THE

AMERICAN NATURALIST.

Vol. VIII.—OCTOBER, 1874.—No. 10.

EXPERIMENTS ON THE SUPPOSED AUDITORY APPARATUS OF THE MOSQUITO.*

BY PROF. A. M. MAYER.

Ohm states in his proposition that the ear experiences a simple sound only when it receives a pendulum-vibration, and that it decomposes any other periodic motion of the air into a series of pendulum-vibrations, to each of which corresponds the sensation of a simple sound. Helmholtz, fully persuaded of the truth of this proposition, and seeing its intimate connection with the theorem of Fourier, reasoned that there must be a cause for it in the very dynamic constitution of the ear; and the previous discovery by the Marquis of Corti of several thousand† rods of graded sizes in the *ductus cochlearis* indicated to Helmholtz that these were suitable bodies to effect the decomposition of a composite sonorous wave by their co-vibrating with its simple harmonic elements. This supposed function of the Corti organ gave a rational expla-

*Reprinted, with a few corrections by the author, from the American Journal of Science and Arts, Aug., 1874.

† "But all of the propositions on which we have based the theory of consonance and dissonance rests solely on a minute analysis of the sensations of the ear. This analysis could have been made by any cultivated ear, without the aid of theory, but the leading-thread of theory, and the employment of appropriate means of observation, have facilitated it in an extraordinary degree.

"Above all things I beg the reader to remark that the hypothesis on the co-vibration of the organs of Corti has no immediate relation with the explanation of consonance and dissonance, which rests solely on the facts of observation, on the beats of harmonics and of resultant sounds."—Helmholtz, Tonempfindungen, p. 342.

Entered, according to Act of Congress, in the year 1874, by the Peabody Academy of Science, in the Office of the Librarian of Congress, at Washington.

nation of the theorem of Ohm, and furnished "a leading thread" which conducted Helmholtz to the discoveries contained in his renowned work, "Die Lehre von den Tonempfindungen."* In this book he first gave the true explanation of timbre, and revealed the hidden cause of musical harmony, which, since the days of Pythagoras, had remained a mystery to musicians and a problem to philosophers.

It may, perhaps, never be possible to bring Helmholtz's hypothesis of the mode of audition in the higher vertebrates to the test of direct observation, from the apparent hopelessness of ever being able to experiment on the functions of the parts of the inner ear of mammalia. The cochlea, tunnelled in the hard temporal bone, is necessarily difficult to dissect, and even when a view is obtained of the organ of Corti, its parts are rarely *in situ;* and, moreover, they generally have had their natural structure altered by the acid with which the bone has been saturated to render it soft enough for dissection and for the cutting of sections for the microscope.

As we descend in the scale of development, from the higher vertebrates, we observe the parts of the outer and middle ear disappearing, while at the same time we see the inner ear gradually advancing toward the surface of the head. The external ear, the auditory canal, the tympanic membrane, and with the latter the now useless ossicles, have disappeared in the lower vertebrates, and there remains but a rudimentary labyrinth.

Although the homological connections existing between the vertebrates and articulates, even when advocated by naturalists, are certainly admitted to be imperfect, yet we can hardly suppose that the organs of hearing in the articulates will remain stationary or retrograde, but rather that the essential parts of their apparatus of audition, and especially that part which receives the aerial vibrations, will be more exposed than in higher organisms. Indeed, the very minuteness of the greater part of the articulates would indicate this, for a tympanic membrane placed in vibratory communication with a modified labyrinth, or even an auditory capsule with an outer flexible covering, would be useless to the greater number of insects for several reasons; first, such an apparatus, unless occupying a large proportion of the volume of an insect,

* According to Waldeyer, there are 6,500 inner and 4,500 outer pillars in the organ of Corti.

would not present surface enough for this kind of receptor of vibrations; and secondly, all non-aquatic vertebrates have an inner ear formed so as to bring the aerial vibrations, which strike the tympanic membrane, to bear with the greatest effect on the auditory nerve filaments, and the minuteness of insects precludes this condition. Finally, the hard test, characteristic of the articulates, sets aside the idea that they receive the aerial vibrations through the covering of their bodies, like fishes, whose bodies are generally not only larger and far more yielding, but are also immersed in water which transmits vibrations with $4\frac{1}{4}$ times the velocity of the same pulses in air and with a yet greater increase in intensity. For these reasons, I imagine that those articulates which are sensitive to sound, and also emit characteristic sounds, will prove to possess receptors of vibrations external to the general surface of their bodies, and that the proportions and situation of these organs will comport with the physical conditions necessary for them to receive and transmit vibrations to the interior ganglia.

Naturalists, in their surmises as to the positions and forms of the organ of hearing in insects, have rarely kept in view the important consideration of those physical relations which the organ must bear to the aerial vibrations producing sound, and which we have already pointed out. The mere descriptive anatomist of former years could be satisfied with his artistic faculty for the perception of form, but the student of these days can only make progress by constantly studying the close relations which necessarily exist between the minute structure of the organs of an animal and the forces which are acting in the animal, and which traverse the medium in which the animal lives. The want of appreciation of these relations, together with the fact that many naturalists are more desirous to describe many new forms than to ascertain the function of one well known form, which may exist in all animals of a class, has tended to keep many departments of natural history in the condition of mere descriptive science. Those who are not professed naturalists appreciate this perhaps more than the naturalists themselves, who are imbued with that enthusiasm which always comes with the earnest study of any one department of nature; for the perusal of those long and laboriously precise descriptions of forms of organs, without the slightest attempt, or even suggestion, as to

their uses, affects a physicist with feelings analogous to those experienced by one who peruses a well classified catalogue descriptive of physical instruments, while of the uses of these instruments he is utterly ignorant.

The following views, taken from the "Anatomy of the Invertebrata, by C. Th. v. Siebold," will show how various are the opinions of naturalists as to the location and form of the organs of hearing in the *Insecta*. "There is the same uncertainty concerning the organs of audition (as concerning the olfactory organs). Experience having long shown that most insects perceive sounds, this sense has been located sometimes in this and sometimes in that organ. But in their opinion, it often seems to have been forgotten, or unthought of, that there can be no auditory organ without a special auditory nerve, which connects directly with an acoustic apparatus capable of receiving, conducting and concentrating the sonorous undulations. (The author who has erred most widely in this respect is L. W. Clarke, in Mag. Nat. Hist., Sept., 1838, who has described at the base of the antennæ of *Carabus nemoralis* Illig. an auditive apparatus composed of an *Auricula*, a *Meatus auditorius externus* and *internus*, a *Tympanum* and *Labyrinthus*, of all of which there is not the least trace. The two white convex spots at the base of the antennæ of *Blatta orientalis*, and which Treviranus has described as auditory organs, are, as Burmeister has correctly stated, only rudimentary accessory eyes. Newport and Goureau think that the antennæ serve both as tactile and as auditory organs. But this view is inadmissible, as Erichson has already stated, except in the sense that the antennæ, like all solid bodies, may conduct sonorous vibrations of the air; but, even admitting this view, where is the auditory nerve? for it is not at all supposable that the antennal nerve can serve at the same time the function of two distinct senses.)

"Certain Orthoptera are the only Insecta with which there has been discovered, in these later times, a single organ having the conditions essential to an auditory apparatus. This organ consists, with the Acrididæ, of two fossæ or conchs, surrounded by a projecting horny ring, and at the base of which is attached a membrane resembling a tympanum. On the internal surface of this membrane are two horny processes, to which is attached an extremely delicate vesicle filled with a transparent fluid and representing a membranous labyrinth. This vesicle is in connection

with an auditory nerve which arises from the third thoracic ganglion, forms a ganglion on the tympanum, and terminates in the immediate neighborhood of the labyrinth by a collection of cuneiform, staff-like bodies with very finely-pointed extremities (primitive nerve-fibres?), which are surrounded by loosely-aggregated, ganglionic globules. (This organ has been taken for a soniferous apparatus by Latreille. J. Müller was the first who fortunately conceived that with *Gryllus hieroglyphus* this was an auditory organ. He gave, however, the interpretation only as hypothetical; but I have placed it beyond all doubt by careful researches made on *Gomphoceros*, *Oedipoda*, *Podisma*, *Caloptenus* and *Truxalis*.")

"The Locustidæ and Achetidæ have a similar organ, situated in the fore-legs directly below the coxo-tibial articulation. With a part of the Locustidæ (*Meconema*, *Barbitistes*, *Phancroptera*, *Phylloptera*), there is on each side of this point a fossa, while with another portion of this family there are, at this same place, two more or less spacious cavities (auditory capsules) provided with orifices opening forward. These fossæ and these cavities have each, on their internal surface, a long-oval tympanum. The principal trachean trunk of the leg passes between two tympanums, and dilates, at this point, into a vesicle whose upper extremity is in connection with a ganglion of the auditory nerve. This last arises from the first thoracic ganglion, and accompanies the principal nerve of the leg. From this ganglion in question passes off a band of nervous substance, which stretches along the slightly excavated anterior side of the trachean vesicle. Upon this band is situated a row of transparent vesicles containing the same kind of cuneiform, staff-like bodies, mentioned as occurring with the Acrididæ. The two large trachean trunks of the fore-legs open by two wide, infundibuliform orifices on the posterior border of the prothorax, so that here, as with the Acrididæ, a part of this trachean apparatus may be compared to a *Tuba Eustachii*. With the Achetidæ, there is, on the external side of the tibia of the fore-legs, an orifice closed by a white, silvery membrane (tympanum), behind which is an auditory organ like that just described. (With *Acheta achatina* and *italica*, there is a tympanum of the same size, on the internal surface of the legs in question; but it is scarcely observable with *Acheta sylvestris*, *A. domestica* and *A. campestris*.)"

Other naturalists have placed the auditory apparatus of diurnal lepidoptera in their club-shaped antennæ; of bees at the root of their maxillæ; of *Melolontha* in their antennal plates; of *Locusta viridissima* in the membranes which unite the antenna with the head.

I think that Siebold assumes too much when he states that the existence of a tympanic membrane is the only test of the existence of an auditory apparatus. It is true that such a test would apply to the non-aquatic vertebrates, but their homologies do not extend to the articulates; and besides, any physicist can not only conceive of, but can actually construct other receptors of aerial vibrations, as I will soon show by conclusive experiments. Neither can I agree with him in supposing that the antennæ are only tactile organs, for very often their position and limited motion would exclude them from this function;* and, moreover, it has never been proved that the antennæ, which differ so much in their forms in different insects, are always tactile organs. They may be used as such in some insects; in others, they may be organs of audition; while in other insects they may, as Newport and Goureau surmise, have both functions; for, even granting that Müller's law of the specific energy of the senses extends to the insects, yet the anatomy of their nervous system is not sufficiently known to prevent the supposition that there may be two distinct sets of nerve fibres in the antennæ or in connection with their bases; so that the antennæ may serve both as tactile and as auditory organs; just as the hand, which receives at the same time the impression of the character of the surface of a body and of its temperature; or, like the tongue, which at the same time distinguishes the surface, the form, the temperature and the taste of a body. Finally, I take objection to this statement: "Newport and Goureau think that the antennæ serve both as tactile and auditory organs. But this view is inadmissible, as Erichson has already stated, except in the sense that the antennæ, like all solid bodies, may conduct sonorous vibrations of the air." Here, evidently, Siebold had not in his mind the physical relations which exist between two bodies which give exactly the same number of vibrations; for it is well known that when one of them vibrates, the other will be set into vibration by

* Indeed, they are often highly developed in themselves while accompanied by *palpi*, which are properly placed, adequately organized and endowed with a range of motion suitable to an organ intended for purposes of touch.

the impacts sent to it through the intervening air. Thus, if the fibrillæ on the antennæ of an insect should be tuned to the different notes of the sound emitted by the same insect, then when these sounds fell upon the antennal fibrils, the latter would enter into vibration with those notes of the sound to which they were severally tuned; and so it is evident that not only could a properly constructed antenna serve as a receptor of sound, but it would also have a function not possible in a membrane; that is, it would have the power of analyzing a composite sound by the co-vibration of its various fibrillæ to the elementary tones of the sound.

The fact that the existence of such an antenna is not only supposable but even highly probable, taken in connection with an observation I have often made in looking over entomological collections; viz: that fibrillæ on the antennæ of noctural insects are highly developed, while on the antennæ of diurnal insects they are either entirely absent or reduced to mere rudimentary filaments, caused me to entertain the hope that I should be able to confirm my surmises by actual experiments on the effects of sonorous vibrations on the antennal fibrillæ; also, the well known experiments of Hensen,* and the inferences of Dr. Johnston from anatomical studies of the antennæ of the Culex, encouraged me to seek in aerial insects for phenomena similar to those Hensen had found in the decapod, the Mysis, and thus to discover in nature an apparatus whose functions are the counterpart of those of the apparatus with which I gave the experimental confirmation of Fourier's theorem, and similar to the supposed functions of the rods of the organ of Corti.

The beautiful structure of the plumose antennæ of the male Culex is well known to all microscopists; and these organs at once recurred to me as suitable objects on which to begin my experiments. The antennæ of these insects are twelve-jointed and from each joint radiates a whorl of fibrils, and the latter gradually decrease in their lengths as we proceed from those of the second joint from the base of the antenna to those of the second joint from the tip. These fibrils are highly elastic and so slender that their lengths are over three hundred times their diameters. They taper slightly, so that their diameter at the base is to the diameter near the tip as 3 to 2.

* Studies on the organ of hearing in the Decapods. "Journal of Scientific Zöology" of Siebold and Kölliker, Vol. xiii.

I cemented a live male mosquito with shellac to a glass slide and brought to bear on various fibrils a $\frac{1}{8}$th objective. I then sounded successively, near the stage of the microscope, a series of tuning-forks with the openings of their resonant boxes turned toward the fibrils. On my first trials with an Ut_4 fork, of 512 v. per sec., I was delighted with the results of the experiments, for I saw certain of the fibrils enter into vigorous vibration, while others remained comparatively at rest.

The table of experiments which I have given is characteristic of all of the many series which I have made. In the first column (A) I have given the notes of the forks in the French notation, which König stamps upon his forks. In the second (B) are the amplitudes of the vibrations of the end of the fibril in divisions of the micrometer scale; and in column (C) are the values of these divisions in fractions of a millimetre.

A.	B.	C.
Ut_2	·5 div.	·0042 mm.
Ut_3	2·5	·0200
Mi_3	1·75	·0147
Sol_3	2·0	·0168
Ut_4	6·0	·0504
Mi_4	1·5	·0126
Sol_4	1·5	·0126
B_4^{b-}	1·5	·0126
Ut_5	2·0	·0168

The superior effect of the vibrations of the Ut_4 fork on the fibril is marked, but thinking that the differences in the observed amplitudes of the vibrations might be owing to differences in the intensities of the various sounds, I repeated the experiment, but vibrated with lower intensities the forks which gave the greater amplitudes of co-vibration; and although I observed an approach toward equality of amplitude, yet the fibre gave the maximum swings when Ut_4 was sounded, and I was persuaded that this special fibril was tuned to unison with Ut_4 or to some other note within a semitone of it. The differences of amplitude given by Ut_4 and Sol_3 and Mi_4 are considerable, and the table also brings out the interesting observation that the lower (Ut_3) and the higher (Ut_5) harmonics of Ut_4 cause greater amplitudes of vibration than any intermediate notes. As long as a universal method for the determination of the relative intensities of sounds of different pitch remains undiscovered, so long will the science of acoustics remain

in its present vague qualitative condition.* Now, not having the means of equalizing the intensities of the vibrations issuing from the various resonant boxes, I adopted the plan of sounding, with a bow, each fork with the greatest intensity I could obtain. I think that it is to be regretted that König did not adhere to the form of fork, with *inclined prongs*, as formerly made by Marloye; for with such forks one can always reproduce the same initial intensity of vibration by separating the prongs by means of the same cylindrical rod which is drawn between them. Experiments similar to those already given revealed a fibril tuned to such perfect unison with Ut_3 that it vibrated through 18 divisions of the micrometer or ·15 mm., while its amplitude of vibration was only 3 div. when Ut_4 was sounded. Other fibrils responded to other notes, so that I infer from my experiments on about a dozen mosquitoes that their fibrils are tuned to sounds extending through the middle and next higher octave of the piano.

To subject to a severe test the supposition I now entertained, that the fibrils were tuned to various periods of vibration, I measured with great care the lengths and diameters of two fibrils, one of which vibrated strongly to Ut_3, the other as powerfully to Ut_4; and from these measures I constructed in homogeneous pine wood two gigantic models of the fibrils; the one corresponding to the Ut_3 fibril being about one metre long. After a little practice I succeeded in counting readily the number of vibrations they gave when they were clamped at one end and drawn from a horizontal position. On obtaining the ratio of these numbers I found that

* I have recently made some experiments in this direction, which show the possibility of eventually being able to express the intensity of an aerial vibration directly in fraction of Joule's Dynamical Unit, by measuring the heat developed in a slip of sheet rubber stretched between the prongs of a fork and enclosed in a compound thermo-battery. The relative intensities of the aerial vibration produced by the fork when engaged in heating the rubber, and when the rubber is removed, can be measured by the method I described in the Amer. Jour. Sci., Feb., 1873. Of course if we can determine the amount of heat produced per second by a known fraction of the intensity, we have the amount produced by the vibration with its entire intensity. Then means can be devised by which the aerial vibration produced by this fork can always be reproduced with the same intensity. This intensity, expressed in fraction of Joule's unit, is stamped upon the apparatus, which ever afterward serves as a true measure for obtaining the intensities of the vibrations of all simple sounds having the same pitch as itself. The same operation can be performed on other forks of different pitch, and so a series of intensities of different periods of vibration is obtained expressed in a corresponding series of fractions of Joule's unit. Recent experiments have given one one hundred thousandth of a Joule's unit as the approximate dynamic equivalent of ten seconds of aerial vibrations produced by an Ut_3 fork, set in motion by intermittent electro-magnetic action and placed before a resonator.

it coincided with the ratio existing between the numbers of vibrations of the forks to which co-vibrated the fibrils of which these pine rods were models.

The consideration of the relations which these slender, tapering, and pointed fibrils must have to the aerial pulses acting on them, led me to discoveries in the physiology of audition which I imagine are entirely new. If a sonorous wave falls upon one of these fibrils so that its wave-front is at right angles to the fibril, and hence the direction of the pulses in the wave are in the direction of the fibril's length, the latter cannot be set in vibration; but if the vibrations in the wave are brought more and more to bear athwart the fibril it will vibrate with amplitudes increasing until it reaches its maximum swing of co-vibration, when the wave-front is parallel to its length and therefore the direction of the impulses on the wave are at right angles to the fibril. These curious surmises I have confirmed by many experiments made in the following manner. A fork which causes a strong co-vibration in a certain fibril is brought near the microscope, so that the axis of the resonant box is perpendicular to the fibril and its opening is toward the microscope. The fibril, in these circumstances, enters into vigorous vibration on sounding the fork; but, on moving the box around the stage of the microscope so that the axis of the box always points toward the fibril, the amplitudes of vibration of the fibril gradually diminish, and when the axis of the box coincides with the length of the fibril, and therefore the sonorous pulses act on the fibril in the direction of its length, the fibril is absolutely stationary and even remains so when the fork, in this position, is brought quite close to the microscope. These observations at once revealed to me a new function of these organs; for if, for the moment, we assume that the antennæ are really the organs which receive aerial vibrations and transmit them to an auditory capsule, or rudimentary labyrinth, then these insects must have the faculty of the perception of the direction sound more highly developed than in any other class of animals. The following experiments will show the force of this statement and at the same time illustrate the manner in which these insects determine the direction of a sonorous centre. I placed under the microscope a live mosquito, and kept my attention fixed upon a fibril which co-vibrated to the sound of a tuning-fork, which an assistant placed in unknown positions around the microscope. I then rotated the stage of the

instrument until the fibril ceased to vibrate, and then drew a line on a piece of paper, under the microscope, in the direction of the fibril. On extending this line, I found that it always cut within 5° of the position of the source of the sound. The antennæ of the male mosquito have a range of motion in a horizontal direction, so that the angle included between them can vary considerably inside and outside of 40°,* and I conceive that this is the manner in which these insects during night direct their flight toward the female. The song of the female vibrates the fibrillæ of one of the antennæ more forcibly than those of the other. The insect spreads the angle between his antennæ, and thus, as I have observed, brings the fibrillæ, situate within the angle formed by the antennæ, in a direction approximately parallel to the axis of the body. The mosquito now turns his body in the direction of that antenna whose fibrils are most affected, and thus gives greater intensity to the vibrations of the fibrils of the other antenna. When he has thus brought the vibrations of the antennæ to equality of intensity, he has placed his body in the direction of the radiation of the sound, and he directs his flight accordingly; and from my experiments it would appear that he can thus guide himself to within 5° of the direction of the female.

Some may assume from the fact of the co-vibration of these fibrils to sounds of different pitch, that the mosquito has the power of decomposing the sensation of a composite sound into its simple components, as is done by the higher vertebrates; but I do not hold this view, but believe that the range of co-vibration of the fibrils of the mosquito is to enable it to apprehend the varying pitch of the sounds of the female. In other words, the want of definite and fixed pitch to the female's song demands for the receiving apparatus of her sounds a corresponding range of co-vibration, so that instead of indicating a high order of auditory development it is really the lowest, except in its power of determining the direction of a sonorous centre, in which respect it surpasses by far our own ear.†

---

* The shafts of the antennæ include an angle of about 40°. The basal fibrils of the antennæ form an angle of about 90,° and the terminal fibrils an angle of about 30°, with the axis of the insect.

† Some physiologists, attempting to explain the function of the semicircular canals, assume, because these canals are in three planes at right angles to each other, that they serve to fix in space a sonorous centre, just as the geometrician by his three coördinate planes determines the position of a point in space. But this assumption is fan-

The auditory apparatus we have just described does not in the least confirm Helmholtz's hypothesis of the functions of the organ of Corti; for the supposed power of that organ to decompose a sonorous sensation depends upon the existence of an auditory nerve differentiated as highly as the co-vibrating apparatus, and in the case of the mosquito there is no known anatomical basis for such an opinion. In other words, my researches show external co-vibrating organs whose functions replace those of the tympanic membrane and chain of ossicles in receiving and transmitting vibrations; while Helmholtz's discoveries point to the existence of internal co-vibrating organs which have no analogy to those of the mosquito, because the functions of the former are not to receive and transmit vibrations to the sensory apparatus of the ear, but to give the sensation of pitch and to decompose a composite sonorous sensation into its elements; and this they can only do by their connection with a nervous development whose parts are as numerous as those of the co-vibrating mechanism. Now as such a nervous organization does not exist in insects, it follows that neither anatomical nor functional relations exist between the co-vibrating fibrils on the antennæ and the co-vibrating rods in the organ of Corti, and therefore, that neither Hensen's experiments on the Mysis (assumed by Helmholtz to confirm his hypothesis), nor mine on the mosquito, can be adduced in support of Helmholtz's hypothesis of audition.*

The above described experiments were made with care, and I think that I am authorized to hold the opinion that I have established a physical connection existing between the sounds emitted by the female and the co-vibrations of the antennal fibrillæ of the male mosquito; but only a well established physiological relation

---

ciful and entirely devoid of reason; for the semicircular canals are always in the same dynamic relation to the tympanic membrane, which receives the vibration to be transmitted always in one way through the ossicles to the inner ear. Really, we determine the direction of a sound by the difference in the intensities of the effects produced in the two ears, and this determination is aided by the form of the outer ear and by the fact that man can turn his head around a vertical axis. Other mammalia, however, have the power of facilitating the determination of motion by moving the axis of their outer ears into different directions. It is also a fact that when one ear is slightly deaf, that the person unconsciously so affected always supposes a sound to come from the side on which is his good ear.

*Also, the organ of Corti having disappeared in the lower vertebrates, it is not likely that it would reappear in the articulata; and especially will this opinion have weight when we consider that the peculiar function of the organ of Corti is the appreciation of those composite sounds, whose signification mammals are constantly called upon to interpret.

between these co-vibrating parts of the animal and the development of its nervous system will authorize us to state that these are really the auditory organs of the insect. At this stage of the investigation I began a search through the zoological journals, and found nearly all that I could desire in a paper, in vol. iii, 1855, of the Quarterly Journal of the Microscopical Society, entitled "*Auditory apparatus of the Culex Mosquito*, by Christopher Johnston, M. D., Baltimore, U. S."

In this excellent paper I found clear statements showing that its talented author had surmised the existence of some of the physical facts which my experiments and observations have established.* To show that anatomical facts conform to the hypothesis that the antennal fibrils are the auditory organs of the mosquito, I cannot do better than quote the following from Dr. Johnston's paper:

"While bearing in mind the difference between *feeling a noise* and *perceiving a vibration*, we may safely assume with Carus—for a great number of insects, at least,—that whenever true auditory organs are developed in them, their seat is to be found in the neighborhood of the *antennæ*. That these parts themselves are, in some instances, concerned in collecting and transmitting sonorous vibrations, we hold as established by the observations we have made, particularly upon the *Culex mosquito;* while we believe, as Newport has asserted in general terms, that they serve also as tactile organs.

"The male mosquito differs considerably, as is well known, from the female; his body being smaller and of a darker color, and his head furnished with *antennæ* and *palpi* in a state of greater development. (Fig. 92.) Notwithstanding the fitness of his organs for predatory purposes, he is timid, seldom entering dwellings or annoying man, but restricts himself to damp and foul places, especially sinks and privies. The female, on the other hand, gives greater extension to her flight, and attacking our race, is the occasion of no inconsiderable disturbance and vexation during the summer and autumn months.

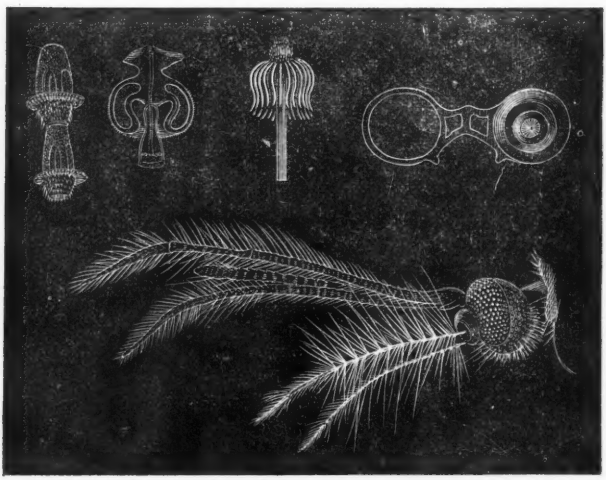
"The head of the male mosquito, about 0·67 mm. wide, is pro-

* A short time before the death of my friend, Prof. Agassiz, he wrote me these words: "I can hardly express my delight at reading your letter. I feel you have hit upon one of the most fertile mines for the elucidation of a problem which to this day is a puzzle to naturalists, the seat of the organ of hearing in Articulates."

vided with lunate eyes, between which in front superiorly are found two pyriform capsules nearly touching each other, and having implanted into them the very remarkable antennæ.

"The capsule, measuring about 0·21 mm., is composed of a horny substance, and is attached posteriorly by its pedicle, while anteriorly it rests upon a horny ring, united with its fellow by a transverse fenestrated band, and to which it is joined by a thin elastic membrane. Externally it has a rounded form, but internally it resembles a certain sort of lamp shade with a constriction near its middle;

Fig. 92.



Auditory Apparatus of the Mosquito.

and between this inner cup and outer globe there exists a space except at the bottom or proximal end, where both are united.

"The antennæ are of nearly equal length in the male and the female.

"In the male, the antennæ is about 1·75 mm. in length, and consists of fourteen joints, twelve short and nearly equal, and two long and equal terminal ones, the latter measuring (together) 0·70 mm. Each of the shorter joints has a fenestrated skeleton with an external investment, and terminates simply posteriorly,

but is encircled anteriorly with about forty *papillæ*, upon which are implanted long and stiff hairs, the proximal sets being about 0·79 mm. and the distal ones 0·70 mm. in length; and it is beset with minute bristles in front of each whorl.

"The two last joints have each a whorl of about twenty short hairs near the base.

"In the female the joints are nearly equal, number but thirteen, and have each a whorl of about a dozen small hairs around the base. Here, as well as in the male, the parts of the antennæ enjoy a limited motion upon each other, except the basal joint, which, being fixed, moves with the capsule upon which it is implanted.

"The space between the inner and outer walls of the capsule, which we term confidently the auditory capsule,* is filled with a fluid of moderate consistency, opalescent and containing minute spherical corpuscles, and which probably bears the same relation to the nerve as does the lymph in the scalæ of the cochlea of higher animals. The nerve itself, of the antenna, proceeds from the first or cerebral ganglion, advances toward the pedicle of the capsule in company with the large trachea, which sends its ramifications throughout the entire apparatus, and, penetrating the pedicle, its filaments divide into two portions. The central threads continue forward into the antenna, and are lost there; the peripheral ones, on the contrary, radiate outward in every direction, enter the capsular space, and are lodged there for more than half their length in *sulci* wrought in the inner wall or cup of the capsule.

"In the female the disposition of parts is observed to be nearly the same, excepting that the capsule is smaller, and that the last distal antennal joint is rudimental.

"The proboscis does not differ materially in the two sexes; but the palpi, although consisting in both instances of the same number of pieces, are very unlike. In the female they are extremely short, but in the male attain the length of 2·73 mm.; while the proboscis measures but 2·16 mm. They are curved upward at the extremity.

"* * * The position of the capsules strikes us as extremely favorable for the performance of the function which we assign to them; besides which there present themselves in the same light

*See fig 92

the anatomical arrangement of the capsules, the disposition and lodgment of the nerves, the fitness of the expanded whorls for receiving, and of the jointed antennæ fixed by the immovable basal joint for transmitting, vibrations created by the sonorous undulations. The intra-capsular fluid is impressed by the shock, the expanded nerve appreciates the effect of the sound, by the quantity of the impression; of the pitch, or quality by the consonance of particular whorls of stiff hairs, according to their lengths; and of the direction in which the undulations travel, by the manner in which they strike upon the antennæ, or may be made to meet either antennæ in consequence of an opposite movement of that part.

"That the male should be endowed with superior acuteness of the sense of hearing appears from the fact, that he must seek the female for sexual union either in the dim twilight or in the dark night, when nothing but her sharp humming noise can serve him as a guide. The necessity for an equal perfection of hearing does not exist in the female; and, accordingly, we find that the organs of the one attain a development which the others never reach. In these views we believe ourselves to be borne out by direct experiment, in connection with which we may allude to the greater difficulty of catching the male mosquito.

"In the course of our observations we have arrived at the conclusion, that the antennæ serve to a considerable extent as organs of touch in the female; for the palpi are extremely short, while the antennæ are very movable, and nearly equal the proboscis in length. In the male, however, the length and perfect development of the palpi would lead us to look for the seat of the tactile sense elsewhere, and, in fact, we find the two apical antennal joints to be long, movable, and comparatively free from hairs; and the relative motion of the remaining joints very much more limited."

My experiments on the mosquito began late in the fall, and therefore I was not able to extend them to other insects. This spring I purpose to resume the research, and will experiment especially on those orthoptera and hemiptera which voluntarily emit distinct and characteristic sounds.

THE GOSSAMER SPIDER.*

BY DR. G. LINCECUM.

DECEMBER is, in Texas, the month for ballooning spiders to emigrate. Webster says, "gossamer, a fine, filmy substance like cobwebs floating in the air, in calm, clear weather, especially in autumn, and is probably formed by a species of spider." Pretty good for a dictionary maker. But he didn't know how it happened to be floating in the air.

Sure enough, that fine, filmy substance is formed by a little spider. I have seen them making it. It is a balloon, and if Webster had caught one of those floating locks of gossamer before it reached a landing place, he would have found the little aeronaut and half a dozen young ones aboard of it. The balloon is the plan adopted by that particular species of Arachnidæ, to scatter widecast its young ones.

This species of spider constructs nets and snares, and, like many other species of the family, its net is circular, very regularly and systematically constructed, and thoughtfully placed in an open passage way, seven or eight feet from the ground between two bushy trees, and above the contingency of being broken by a roaming cow or loose horse.

In setting and establishing the two first brace lines between the two trees it has selected for its net, it displays much sagacity and ingenuity, with a thorough knowledge of the powers of the wind, and the best possible method and position to avail itself of its uses. Climbing up the tree situated to the windward, it takes position, at the proper elevation on the point of the longest twig it can find that projects towards the other tree of its selection; and spinning one of its gossamer webs of the proper length, patiently waits for a breath of air to waft it across the vacant space of ten to twenty feet and lash its viscid extremity to some projecting twig or leaf of the opposite tree. It holds the line in its hand, feels when it strikes, and instantly making the home end fast, strikes out boldly on the microscopic thread, lets go another thread as she travels, and is soon observed lashing down the ends

*Communicated by the author to the Smithsonian Institution and published by permission of Prof. Henry.

of the now double line, to a twig of the other tree. This done, it runs back and forth on it, spinning a thread every trip until the line is ten or fifteen ply.

It now places itself on another twig of the windward tree, as nearly under the first line as possible and six or eight feet below, lets go another thread. As soon as it feels it has caught on the opposite tree it fastens down the home end, and hastens to reënact all we saw it perform on the first line. It seems to be much elated and encouraged by its successes, and, now hurriedly, is seen climbing up the first tree, and very soon is engaged at work as near the middle of the upper line, as could have been obtained by actual measurement. Soon it is observed descending spinning out a thread as it goes, it being safely fastened to the upper line. It swings down until it is somewhat below the lower line; but finds that the thread it hangs on, is half a yard or more to one side of its lower line. It now, after a moment's reflection, attempts to swing, pendulum-like, at the end of its thread to and from the lower line. The spider soon ascertained that success did not lie in that experiment; and wound up the thread it was hanging on until it regained its position on the middle of the upper line. It was very nearly calm, and it rapidly spun out a long wet thread, which, light as was the breeze, passed above the lower brace line. It was however continuously extended until it struck amongst the brush some distance away. The ingenious little workman continued to spin out the thread, until the slack of it bending down came in contact and adhered to the lower line. Feeling the entanglement, it immediately ran down, cut and cast loose the surplus end of the thread, carried the end in hand to a point at right angles with the attachment to the line above, made it fast, then quickly ran about a yard along the lower brace, attached a thread, returning, ran up the middle line, thence along the upper brace to a point perpendicular to where it had attached the thread in hand to the lower brace, drew up the slack and made it fast. Then passing on the upper brace to a point about a yard beyond the middle dropped line, made a thread fast and returning descended the middle line, carrying the thread to a point at right angles with its attachment above, and giving it the proper tension, made it fast. And now, laying three or four threads on each of these three stay lines, the balance of the work, though tedious, was easily accomplished.

After laying the radiating lines, it goes down to the centre, and carefully measuring with its right hind leg, seizes with its foot one of the lines, and drawing it down forcibly, until it touches the web vent; it adheres and is instantly let go. In its recoil, there is seen to be drawn out a milk like substance; this lessens into a very fine web which instantly dries. It then moves onwards to the next line and with the same hind foot seizes it at the proper measurement, draws it down as before until it touches the web fount, lets it recoil and spin out the gossamer web; and so on, from line to line, measuring the meshes exactly the same distance moving to the left; the circular line is put on spirally.

The gossamer spider will weigh near two grains; it is well formed, of a grayish pea green, the legs rather long. Quick in its movements, but a little timid; it will drop its work and run on the approach of a stranger. One species of mud dauber destroys multitudes of the gossamer spiders.

When, in the last days of November there comes a clear day, temperature 60° Fah. wind gently from the south; at about one o'clock, P. M., and afterwards during the succeeding three hours, may be seen, in this latitude at various heights and distance, very many white locks of gossamer floating smoothly in the air, all going with the wind. These are the balloons of the gossamer spider. And there is a mother and half a dozen or more young spiders aboard of every one of them.

Each balloon is furnished with two long lines at the forward end, which may be seen, waving and flapping in the wind as they fly, and seeming to aid in preserving the equable position of the light floating craft.

Towards four o'clock, P. M., the spectator will observe that the balloons are beginning to descend; and at the same time he will see great numbers of long glittering webs, detached and floating at random all rising higher as they go on with the wind.

Meanwhile the balloons with their freight are whirling, not very rapidly downwards, until they strike some tall weed or grass, when they become entangled, and the passengers instantly leap out, and spinning out a web swing themselves down to the ground.

If the observer is near enough when the balloon strikes he can see all this.

I have noticed these balloons, when the wind was brisk passing very rapidly, at an altitude of one or two thousand feet. There

is no telling where they came from or how far they might float. 150, or 200 miles perhaps. Thus is scattered the species over vast districts, which, no doubt, is the object of their aeronautic journey.

When they intend to make an ascension, they fix themselves on some extreme point of the branch of a tree, or weed or corn tassel; there carefully spin out a lock of white gossamer five or six inches long and two inches wide in the middle, tapering towards the ends; holding it all the time in the gentle breeze by a thread two or three inches long, which, being attached to the end of the selected point, detains the balloon until it is finished. They then spin out at the bow two lines thirty or forty feet in length, another at the stern twenty or thirty feet long, then cut the cable and float briskly upwards and forwards on an inclined plane.

I once observed one of these spiders at work on the upper corner of an open, outside door shutter. She was spinning gossamer, of which she was forming a balloon; and clinging to her thorax was a little cluster of minute, young spiders. She finished up the body of the balloon; threw out the long bow lines, which were flapping and fluttering on the now gently increasing breeze, several minutes before she got all ready for the ascension. She seemed to be fixing the bottom and widening her hammock-shaped balloon. And now the breeze being suitable, she moved to the cable in the stern, severed it, and her craft bounded upwards and soaring away northwards, was soon beyond the scope of my observation. I was standing near when it was preparing to cast loose the cable; and had thought I would arrest its flight but it bounded away with such a sudden hop, that I missed and it was gone.

ON THE NESTING OF CERTAIN HAWKS, ETC.

BY DR. ELLIOTT COUES, U. S. A.

In a recent number of the Naturalist I gave some account of the nidification of Swainson's buzzard (*Buteo Swainsoni*), but had nothing to say of the eggs, as I took the field last season too late for them. The present year I have secured numerous sets, and

noticed an interesting variation from the usual mode of nesting, necessarily brought about by the entire absence of trees. In Montana, as in most of Dakota, Swainson's buzzard occurs in great numbers over large areas of almost unbroken, arid and cactus-ridden prairie, where, even along the water-courses, there may be no trees or bushes for many miles. Several of the northern tributaries of the Milk river, which we have crossed this season, are entirely unwooded; the streams cut their sinuous course deep into the loose soil of the prairie, making on the convexity of almost every turn a bold perpendicular earth-bank a hundred feet, more or less, in height. To these "cut-banks" as they are called, Swainson's and some other hawks, to be presently mentioned, resort to breed. The nest is composed of small sticks—the stems of sage brush and other rank weeds—with grasses, etc., and is of the usual size and shape; it rests directly on the earth of some little projecting shelf of ground, generally near the top of the embankment. The eggs of this bird I have taken, fresh and in various stages of incubation, from the latter part of June till the middle of July. No one of the numerous sets contained more than two eggs; this is obviously the usual complement, in this latitude at least, though presumably not the maximum. In one instance, I found but a single egg in the nest, so far advanced in incubation that I was satisfied no other would have been laid. These eggs differ, furthermore, from what I believe to be the rule in this genus, in being nearly colorless and unmarked. They are quite like hens' eggs in general appearance, as well as in size and shape. Most of my specimens are uniform dull white, with no more evident markings than such obsolete grayish spots as are frequently observed in the eggs of the marsh hawk (*Circus cyaneus Hudsonicus*); a few have some obvious dirty-brown scratchy spots, in every instance at the small end; none are marked all over, nor are any of them strongly blotched at all. It would have been impossible to predicate the normal character of these eggs upon any rule which might be supposed to hold in this genus. Plain colorless eggs, the well-known exceptions in the cases of many or most species of Buteo, are here the rule.

It may not be generally known that the ferrugineous buzzard (*Archibuteo ferrugineus*) which is accredited, and properly so, with a decidedly western range, is a common species of eastern Montana and the adjoining portions of Dakota, in latitude 49°. I have

frequently seen it this summer along the northern tributaries of Milk river, where I have secured some fine specimens of old and young, and observed its nidification. This is precisely the same as that of *Buteo Swainsoni*, the nest which I found being placed on a little projection on the face of an earth bluff. It contained three young, about ready to take flight, July 18th.

I was still more surprised to find yet a third species of hawk nesting in the same unusual manner. This was the peregrine falcon or duck hawk (*Falco communis*), a bird whose nidification, under varying circumstances, has occasioned some little controversy, and entered into the discussion of the relationship of the American to the European form. I was much gratified to discover the nest, which very few ornithologists have seen in this country, and to note how readily the bird adapted itself to its special surroundings. In this region the falcon may be truthfully said to nest *on the ground;* yet we must remember that it is merely the replacing by an earthen embankment of the rocky crags where the bird is described as usually nesting. In effect the location is the same. One of the two nests I found was almost within rifle-shot of the two spots where Swainson's and the ferrugineous buzzard were respectively nesting. It was almost a burrow in the ground, so completely was it hidden on a little shelf of earth beneath a projecting mass, and further concealed by a tall column of earth nearly washed away from the face of the bank. This nest contained three young ones, just able to fly. On lowering a man down by a rope over the brow of the bank, they left the nest and circled about till two were shot; one parent had been already destroyed; the other was not seen. The third young one was afterward brought to me by a soldier who had managed to capture it alive; it is still in my possession, and is proving itself a spirited and enterprising prisoner. The other nest was on the bare face of a perpendicular embankment, on a slight shelf about twelve feet below the top. It likewise contained three young (July 19th), not yet able to leave the nest. Both parents hovered overhead with loud harsh cries; the male kept at a respectful distance, but the mother bird, more intrepid in the defence of her home, menaced me at close range, till, at one of her swoops, I brought her to the ground. I endeavored without success to lasso the young ones out of the nest; they repeatedly cleared themselves of the noose just as it began to draw upon them; and as the crumbling state of

the bank rendered descent to the nest too dangerous to be tried, I left the family to the care of the father, who, it is to be hoped, has since done more for his family than he did on the occasion just mentioned.

The character of the embankments on which all these hawks nested may be perfectly indicated in the fact that they were also the resort of myriads of cliff swallows (*Hirundo lunifrons*). Thousands of the swallows' nests patched the face of the banks in various places; one large cluster was noticed near a buzzard's nest; while another group was affixed within a few feet of one of the falcon's nests. I was not long enough on the spot to determine whether the swallows were fond of their bold and powerful neighbors or not.

In speaking of this unusual association of swallows and falcons, I am reminded to note a somewhat similar arrangement between a pair of Arkansas flycatchers, and Swainson's buzzard; their nests being in the same tree and but a few feet apart. Both birds were incubating at the time of my visit.

The Arkansas flycatcher (*Tyrannus verticalis*), is one of the commonest of the small birds along the Upper Missouri and the wooded parts of the Milk river and its tributaries. So far as I have observed, however, it will not go into an entirely treeless country. In travelling over the prairie, no sooner do we strike a "*coulé*" (ravine) with scattered cottonwoods and box-elders, than we hear the shrill cries of these birds; and the nest—or several of them—may usually be soon discovered, the nest being bulky, and the trees straggling, with thin foliage. These birds lay later than most species in this country. I have taken fresh eggs up to the middle of July, and am sure there was no previous brood. The nests are in a fork or crotch, generally far out on the limb, but sometimes directly against the trunk; and at any height from five or six to forty or fifty feet. The common kingbird is generally seen in company with this species; I have taken both nests from the same tree. The eggs of the two are indistinguishable; nor can the nests be told apart with certainty; though on an average the Arkansas is the larger, softer and fluffier, with more weedy and downy material and fewer slender rootlets; it is also rather less compactly built. The eggs run from three to six in number. With the same general habits, these two flycatchers may instantly be recognized by the voice; that of the Arkansas is much harsher

and louder than that of the common kingbird, which more nearly resembles the twittering of a martin. The difference is very noticeable when the two species are hovering together overhead, bewailing the spoliation of their homes.

Our common kingbird may be added to the long list of the cowbird's victims, and to the shorter catalogue of those ingenious birds who get rid of the obnoxious egg by building a two-story nest. I have such a one in my collection, with a cowbird's egg safely shut up in the basement.

Nothing that I am aware of has been entered upon the records respecting the nidification of the mountain plover (*Eudromias montana*). I find it breeding quite commonly in all the region immediately north of the Milk river, and extending at least as far east as the mouth of this river. It nests on the open prairie, in June and July. There is nothing peculiar in the nidification; the nest is merely a slight depression, lined with a few grass blades. The only set of eggs I have contains three; and as I have several times noticed the parent leading her brood of three young over the prairie, I conclude that this number, and not four, is the usual complement, in this latitude at least. The eggs are as described in my late work; they are rather peculiar, and little liable to be confounded with those of any of the allied waders. When startled from the nest the bird makes off crouching low, running swiftly but with frequent pauses, and uttering meanwhile a low chattering note, quite unlike the ordinary soft mellow cry. As I have said, the bird nests anywhere on the dry prairie; but if it have any preference, it is for the stretches of low loose grassy ground where the prairie dogs settle, as distinguished from the more arid and gravelly or stony prairie. The period of nesting must be protracted; for I have taken nearly fresh eggs at the same time that I saw broods running about, and but a few days before well feathered young, no longer under charge of the parent were obtained.

The numberless alkaline pools or small lakes with which portions of Dakota and Montana are cursed are the favorite breeding resorts of two very elegant and interesting birds; the avocet, and Wilson's phalarope. These two species are always intimately associated in my mind, so frequently have I found them together, not only in this region, but in Kansas and other parts of the west. The avocet is one of the most conspicuous birds of the saline regions of our Territories. In flight we recognize it at any dis-

tance by its resemblance to a miniature crane; its body white, and wings black, its long blue legs stretched stiffly straight behind, and the measured sweep of its ample wings, unlike the quicker beats of the thin, pointed pinions of its allies. Its voice is also characteristic; the harsh noise is incessant when the breeding places are invaded. This bird must nest quite early; as I found no eggs, and by the middle of July well grown and completely feathered young birds were flocking. These may be distinguished from the adults among other marks, by the curiously swollen condition of the shank; the upper part of the tarsus being two or three times as thick as the tibia. It is much the same with the phalaropes and other waders. As regards the singular bill of the avocet, the amount of curvature of which has occasioned no little discussion, I may observe that I have shot some birds with the bill about as much curved as it is represented to be in Wilson's figure, which has been severely criticised, and others with the bill as straight as Audubon drew it; nor was the difference, so far as I could see, anything more than fortuitous. The degree of swimming power the avocet possesses has also been variously estimated. The bird generally wades about after its food; but on striking a deep place begins to swim without the slightest hesitation; and moreover, I have seen it alight from on wing on deep water, and swim about as freely as a duck. In this respect, the avocet and the phalarope are about on a par.

One of the most generally diffused of the birds that breed along the Upper Missouri and in the Milk river region is the long-billed curlew (*Numenius longirostris*). I have travelled for days together and scarcely lost sight of these birds for an hour, during the daytime; while at night their piercing and lugubrious cries resounded to the howling of the wolves. There is something peculiarly melancholy, and almost foreboding, in their screams, heard in these remote wilds, where the traveller is never entirely free from a sense of contingent danger. The birds breed anywhere on the broad prairie — perhaps oftenest in the vicinity of pools and sloughs, but not necessarily near water. The eggs are mostly laid in June, but there is a wide range in the time. Thus I have taken a set in July, having previously caught young birds. These, like other waders when young, have a curiously clumsy and gawky appearance when running over the prairie, as if their legs were too long and heavy to be easily managed. They may

readily be caught during the first week or two. At this age the bill is about two inches long, comparatively stout throughout, and scarcely decurved.

Among the smaller birds of the boundless prairie, a few species are specially notable. The commonest and most universally diffused is the western horned lark (*Eremophila alpestris leucolæma*); we find it breeding everywhere. It begins to lay very early; the curiously speckled young ones, quite unlike the adults, may be taken any time in June, already flying; while eggs (doubtless of a second brood) may be secured through July. The mode of nesting of the larks, and of the three most conspicuous prairie *fringillaries*, is substantially the same. The three to which I refer are the bay-winged bunting (*Pooecetes gramineus confinis*), the chestnut-collared bunting (*Plectrophanes ornatus*) and Maccown's bunting (*P. Maccownii*). These two *Plectrophanes* are the most characteristic of the prairie sparrows, and are found together in abundance in most of the regions here under consideration. *P. ornatus* however, is rather the more easterly of the two. Thus, it is common all over northern Dakota and the eastern part of Montana; while I have seen none since I came the first few miles up the Milk river, where *P. Maccownii* increases in numbers, then becomes the prevailing, and finally the only species. The chestnut-collared has a very pretty habit of soaring, like Sprague's lark, while the female is incubating, singing in the air, and letting itself gradually down like a parachute, with the wings stretched upward at a right angle with each other — an action that displays the glossy black of the under parts and the white of the tail to the best advantage. Floating thus lightly in the air they remind one of butterflies; and their song, though not of the highest excellence, is sweet, gladsome and musical.

Great numbers of water-fowl stay their flight to nest in the pools and sloughs of our Northern Boundary; among them may be mentioned mallards, widgeons, shovellers, teals, pintails, scaups, buffle-heads and wild geese. To resume the subject with which this slight article began, namely, exceptional modes of nesting, I would say that the geese of this region sometimes nest on the ground around the ponds, as geese ordinarily do, and then again they sometimes *nest in trees*, somewhat like wood ducks, only that they do not enter holes for this purpose. Arboreal nidification of geese sounds strangely, but it is nevertheless true; and it is a well

known circumstance to those persons who inhabit the country, however unenlightened ornithologists may be in the matter. It furnishes a case parallel with that related by Audubon, of the herring gull nesting in communities, in trees.

I will conclude with an observation on the digestive arrangements of the sage cock—a bird which I have only lately seen alive. It has been repeatedly stated to feed exclusively upon sage leaves. All those I shot had the craw full of grasshoppers and other insects, and had nothing else in it. It has also been asserted that the bird has no gizzard; the gizzard is indeed quite thin, so as to appear merely a membranous bag, but for all I could see that the disposition of the muscles is the same as that obtaining in other gallinaceous birds. The case is simply a reduction of the amount of muscle, without any essential change in arrangement. At least this is the result of an off-hand dissection, such as one would be likely to make in the field. The change is an evident adaptation to the soft and succulent or juicy nature of the bird's food—buds, leaves and insects, instead of grain. There is another peculiarity of this bird, also dependent upon its food, and the nature of the digestive process. When flushed it almost invariably acts in the way which has given the green heron (*Ardea virescens*) its inelegant popular appellation.—*Milk River, at* 49°, *July* 25, 1874.

THE METAMORPHOSIS OF FLIES.* I.

BY DR. AUGUST WEISSMAN.

Before I pass to the general results of the foregoing observations a short chronological exhibit of all the processes of development will be useful.

In agreement with all the earlier observations on the embryology of other insects it is apparent that during the life of the larva, in its outer form as well as the internal organs, only the

*Though Weissman's famous work, "The Development of Diptera," was published as long ago as 1864, yet we feel sure our readers will value the translation of a few of the concluding chapters which have not previously been rendered into English. The present chapter is entitled "View of the Phenomena of Development."—A. S. P.

phenomena of growth are manifested, and not a deeper reaching metamorphosis. As the enlargement of an organ by simple growth in the Vertebrates is allied with a new formation of blood vessels, so here the origin of a new trachea is accompanied by the speedy enlargement of muscles and intestine, and with this very important continual increase of the net-work of tracheæ is combined an expansion and increase in volume, so that after the first moulting, on the anterior end of the body, a new pair of stigmata are formed, while the aperture in the hinder one is doubled, and after a second moulting, a three-fold aperture is made. Accompanying this is a certain change in the apparatus of hooks arming the mouth of the larva. All these changes are not of great importance; they lead to no new feature in the organization of the animal; they are series of processes which precede the formation of entirely new organs or parts. Transformation in this last sense occurs only in those parts of the larva, out of which the parts of the adult insects are developed. *The genital glands, as well as the outer skin of the segments bearing the appendages of the fly's body, are already formed in the larva; indeed they are even formed during the development of the embryo.*

We find ourselves in fact almost going back to the encasement theory of Swammerdam, who believed that the larva, pupa and butterfly were imprisoned from the very first in each other, and came to light by the successive casting off of each skin. It is in fact only this, that the parts of the fly* do not all lie perfectly formed within the larva, but exist only as rudiments, and that only a part of the body of the fly is newly formed, while some of the parts will be produced out of the larva. The head and thorax with their appendages are formed within the larva by the gradual development of special cell masses. The abdomen, however, arises through a simple change of a number of larval segments. The head and thorax arise not as a whole out of a single cell mass, but in separate pieces, out of which after pupation the whole form is perfected.

The head arises out of two groups of cells which originate from a nervous filament sent off from the supra-œsophageal ganglion; but each segment of the thorax arises out of four separate groups of cells which are partly inserted in the course of a slender filament, and are in part blended with the peritoneal skin of a trachea.

* This chapter relates wholly to *Musca vomitoria*.

These collections of cells form flat disk-like bodies which are enclosed in a structureless membrane and may be termed the *imaginal disks*. In each imaginal disk of the thorax arises a quarter of a segment with the appendage belonging to it; the two imaginal disks of the head, the appendages of the brain, unite themselves into a hinder division, the eye-disks; and an anterior which forms the germ of the antennæ and remaining portion of the head.

The pupation in Sarcophaga occurs eight or ten days after the exclusion of the larva from the egg. It is accompanied by a marked contraction of the whole body, with an infolding of the first segments.

Under the hardened, barrel-shaped, larva skin [puparium], the true pupa is formed, *i. e.*, the body of the fly enclosed by a special membrane, the pupa-sheath. The process of formation of the body of the fly, while thus enclosed, lasts for four days after the pupation. Then it reaches that stage which in the development of the butterfly is shown by a stripping off of the larva skin, and the *formation* of the pupa is ended; then begins the *development* of the same. This consists in the building up of the external form of the body, and in establishing the position and development of the internal organs. This period can be divided into two sections, which are here described chronologically. The first division consists of the more delicate modelling of the outer form. Hitherto the insect has appeared only in its crudest shape, the appendages of the thorax and head are but rudimentary, neither attaining their full size, nor their definitive form. All these parts are now entirely formed, and are matured in from two to seven days, and already covered with colorless hairs and bristles.

The second division covers the period of the eighth to the twentieth day, during which time the inner organs are completed, and the outer surface of the body assumes its peculiar colors.

The first period, that of the formation of the pupa, lasting from one to four days, begins with the destruction of the four anterior segments of the larva. The hypodermis which gives it its form is loosened, the muscles of the body-walls, as also of the pharynx, the cellular walls of the pharynx itself, the anterior part of the œsophagus, with the sucking stomach, follow next. During this time the thoracic pieces are developed from the imaginal disks; they give origin to the appendages, which are indeed very short, but still each joint can be distinguished, and are nothing but a

projection outwards of these same thoracic pieces. However here — as we had until now thought — the appendages of the imago do not result from a simple thrusting out of the larval hypodermis, as would seem to be correct in a morphological view, which would consider the appendages of the insectean body as projections of the skin, during their development not aborted, but persistent. They are in fact still, however, projections outwards of the skin, though they are formed at a time when the skin has not grown into closed segments. Still we find at the end of the second day the formative disks of the thorax appended to their pedicels (nerves, tracheæ) in the form of swollen transparent vesicles, and within them the thoracic pieces to which they are closely related, with its appendage, can be easily observed. In three days they have attained their perfection, the skin peels off and falls away, and they now become three completed rings, the thoracic segments. At the same time the tracheæ of the larva are thrown off, and then begins the formation of a peculiar tracheary system, which performs its functions only during the pupal period. In its trunks and larger branches it resembles the larval system, but in the terminal rings is unlike anything else. In this respect their structure is very peculiar, in that all the ends project freely into the liquids of the body, and nowhere, as before, do they send fine branches to the different organs. The filling of the new system of air vessels with air does not go on during the remaining moultings, through a removal of the old proximal tubes (*intimaröhren*); this cannot be completely seen during the life of the pupa, but through the cross division of the proximal tubes (*intimaröhren*) in a determined place of the stem near the anterior stigmata.

At the third day the three segments of the thorax unite to form a small ring which posteriorly coalesces with the edge of the fifth larval segment; but the anterior edges are puffed up and are open. In the opening lie loose the chitinous parts of the mouth parts, the apparatus of hooks. The head of the fly is not yet to be seen, but the rudiments of the same are still visible within the thorax. In the two formative disks of the body, which we would consider as appendages to the brain, develop into a vesicle containing the œsophagal ganglion, the head-vesicle, on which the eyes and antennæ are already indicated, and from under whose hinder edge the proboscis grows out. On the fourth day the head, which has advanced forwards from within the thorax, comes to light, and is

accompanied by an uninterrupted, strong contraction of the eight hinder segments of the larva still contained within. These last are shortened, and soon assume the form of the abdomen of the adult fly. The head thus presses forwards out of the thorax, keeps pace in development with the thorax; the body of the pupa then lies as a whole contained within the puparium, and thus indicates the end of the first period.

The process of development of the first four days is confined not wholly to the outer crust of the body, but also to the new remodelling, or transformations of some of the inner organs. The nervous centres which had been separated in the larva here become united; an infra-œsophageal ganglion separates (abschnürt) from the ventral cord, and the upper (supra-œsophageal ganglion) divides into two divisions, of which the outer may be considered the central organ of the sense of sight (ganglion opticum) and as the bulb of the compound eyes.

All the anterior and middle portion of the alimentary canal sloughs off, and at the end of four days becomes renewed. This happens only to the œsophagus and chyle-stomach, while the proventricalus and cæcal appendages of the stomach are not thus reproduced. They break up cell by cell; these cells are carried into the chyle-stomach forming there a compact mass, which is surrounded with a peculiar covering, as if encysted. They do not fill up the cavity, but swim in a honey-like liquid which by this time will have been secreted by the cells of the walls. Here the cells are preserved, though the organ is destroyed, thus the reconversion is effected in the walls of the chyle-stomach. Each cell decays by fatty degeneration and in the place of the old cells arise new ones which rebuild the organ. The destruction of the cells is accompanied by a contraction of the muscular walls, and thereby an important shortening of the organ is produced. Next these muscles as well as the tracheæ decay, many branches of which are interwoven around the stomach of the larva; the alimentary canal remains without air-vessels until the last day of the pupa state. As soon as the abdomen has formed, by the contraction of the subcutaneous muscles of the last eight larval segments, the muscles disappear, and at the same time, namely, during the advance of the head, at which time also the nervous centres become pushed forward; they tear away also the degenerated nervous branches, whose terminal threads likewise become

destroyed with the organs in which they ramify. Of the influence of the nervous system on the entire organism, there is nothing to be said since the change of form of the central parts is accompanied by a complete histological transformation, as the interpenetration of their cell masses with fat demonstrates.

The dorsal vessel does not now perform its functions. The animal now consists of a thin cellulose skin, with its contents partly destroyed, in part completely destroyed, and in part already concerned in the new formation of the organs. The entire fat body, cellulose tissue, of the larva, is lost in a liquid mass of fat globules and nuclei, and they are mingled with the decaying muscles, tracheæ, etc. At the end of the first period the contents of the pupal body may be well compared with the contents of the fertilized egg. All visible traces of animal life have ceased; the action of the centres of the expression of animal life is suspended, and out of this chaos of elemental parts the organs are built up anew. One essential difference from the development of the embryo only remains, that at no time are all the inner organs wanting. External activity and decay occur simultaneously. But any internal or external movements are wanting; sense organs and nerves are wanting, and there can be truly said to be no outward impressions received, though an activity may be ascribed to the central parts of the nervous system. Yet a regular flow of fluids does not occur, and the only relative physiological action is that of breathing, *which here goes on as passively as in the egg;* in the one case through the stigmata and tracheæ, in the other by the pores of the egg-shell. An active breathing process, such as goes on in the perfect state, is entirely wanting.

While the decay of the inner organs is going on, or has already taken place, the formative elements begin to develop themselves out of the cell-mass; fat nuclei, fat globules, and flakes of stearine unite into round masses of nucleated spheres, which are capable of building up a membrane around themselves, and embracing a nucleus within. Already in the third, still more in the course of the fourth, day do the appendages of the thorax grow in length, and all arise from a thin cellulose skin, and out of a larval cavity which fills up with fat globules and nuclei as the fat body gradually breaks up. With this begins the metamorphosis of the appendages and of the external form of the body into their definitive form; the period of formation of the body of the pupa

has ended, and now begins the *period of development of the same*. It lasts from the fifth day to the time of exclusion of the fly, and can, as has already been shown above, be divided into two subdivisions, of which the first reaches to the end of the seventh day.

First to be noticed is the formation of the pupa-case, which, however, was in existence at the end of the first period, but lies as the cuticula right on the cellular skin (zellenrinde) by which it was ensheathed. It now rises up and a space filled with clear liquid separates it from the upper surface of the body. The cellular tegument (zellenrinde) of the appendages is thickened, partly by the increase of the cells present, which seem to receive their plastic material by endosmose, but partly through a free formation of new cells by a self division of the nuclei. The whole cavity of the limbs seem to be compactly filled with nuclei which are uniformly from the outer to the innermost transformed into cells.

By the fifth day the last tarsal joint is divided into two lobes, and show the first position of the claws. On the sixth the sutures are more distinct, the pulvilli are formed, and on the seventh day the external form of the limb is completed. The hypodermis divides into two layers whose deeper portion is disposed on the upper surface of the skin and form the hairs and bristles. Inside the limbs only the position of the nerves and tracheæ of the pupa is established, the muscles arise afterwards.

In like manner the wings are formed, their veins arise, the hairs appear; they attain their definitive form and are folded together.

The halteres grow out, and instead of a single hollow, stunted projection, they are completely formed, and hairy, though still colorless. The antennæ also reach the same grade of perfection, and like the appendages, the segments themselves now assume their definite form. The four abdominal segments are formed out of the eight larval segments which originally formed the abdomen of the fly.

While the external form of the body rapidly advances in this manner to its final perfection, corresponding but slower changes are discovered in the viscera. The fatty tissues continually disappear, and as often the cavity of the body is filled more compactly with nucleolated cells, and fat molecules. The newly formed thin œsophagus thickens at the end towards the proventriculus, and indeed the first beginnings of the sucking stomach is indicated at

this period. The chyle-stomach gradually changes in length, its walls are transparent and clear, and it is strikingly demarked from the dark small intestine rendered so by the walls filled with fat corpuscles. With this begins the period of decay, and it reaches on the seventh day its complete development.

Already during the course of seven days usually begins the *second subdivision of the second period* which is characterized by the relative position and development of all the organs of the imago. On the seventh day we find in the cavity of the thorax the first trace of the muscles of the wing. Series of cells of the greatest fineness pass in determinate directions through the liquid masses of fat, and up to the fourteenth day increase in thickness, until finally they lie close together to the lateral spaces of the thorax, and only leave in the median line a slight space for the free passage of the stomach. Their structure is, then, usually definitive, it is a sarcolemmous sheath filled with contracted fibres which lie together in fascicles, and are kept separate from one another by nucleated columns. Meanwhile out of the fragments of the old intestinal canal appears the new, and shortly after this is accomplished there is a union of the small intestine and rectum, and by the tenth day the rectal pouch is placed in relation with the four rectal apillæ. At the same time a new plexus of muscles begins to form on the upper side of the entire intestinal tract.

Still the most important steps in the formation of the principal organs of sense of the fly, the compound eyes, fall into this last section of its developmental history. The ocular disks, which originated out of the hinder division of the brain-appendage, is still connected with the bulb at the beginning of the second period by means of a slender nerve. The bulb gradually extends itself so that it covers the whole interior of the eye-disk, and only becomes separated from it by a thin layer of fat, which has already arisen between the two parts. The bulb shows radiating streaks, which are indications of the nervous threads passing through it. Only out of the eye-disks will the true eyes be formed, *i. e.*, the compartments with the dioptric apparatus, and the perceptive nervous elements. On the twelth day, however, the disks and also each compartment leading out of it, have the very small diameter of 0·051 ^{mm}., which is gradually at the close of the pupa state enlarged five times, while at the same time the cellular elements lying behind each corneous facet, forms for each chamber a crys-

talline body, a nervous thread and cortical substance. The pigment layer begins to form and is finished, and the bulb sends out the ganglion cells at the base of the chambers of the eye. The nervous centres also take on their last definite form, the hinder part of the ventral cord, which already in the first period had extended out from the infra-œsophageal ganglion, and had extended back into the abdomen, now unites with the thoracic knot. A similar longitudinal commissure unites it with the infra-œsophageal ganglion. At the last moment the central portions send out nerves to the sides into the thoracic muscles and into the limbs, in which during the tenth and eleventh day the muscles begin to form, and afterwards hindwards into the abdomen.

Of the larval organs only the dorsal vessel is destined to pass over into the last division of the developmental period, but it still suffers a total transformation. A process of fatty degeneration similar to that which took place in the alimentary canal occurs, and on the 12th day it assumes a new form and organization. Meanwhile it is not capable of performing its functions, as the want of a histologically perfect system of muscles proves.

The tracheary system is completed last of all. The first positive condition is assumed on the 15th day, and by the 17th it is generally entirely formed. The trunks arise for the most part by means of the masses of nuclei out of the originally solid series of cells, the terminal branches of the organ out of a single cell; the hollow space between them will form the cavity of the trachea, while they branch out by growing outwards. Yet these cells may for the most part be traced back to the masses of nuclei, but soon and especially within the inner of the bundles of primitive muscles of the thorax, *they arise from an organization of the histological formative elements at hand, i e. the muscular nuclei.* This remarkable fact does not take place without a reaction in the muscular fasciculæ themselves; their sarcolemma disappears and they deteriorate into fascicles of tracheæ wanting the spiral thread.

All the organs which have tracheæ intimately connected with them have the same developed in the last three days. The tracheæ grow out in the nervous centres, in the bulb of the eyes, and the alimentary canal in its entire course is surrounded by a net work of them. They are sent to the rectal papillæ in great abundance and with a peculiar development. The dorsal vessel also and the entire muscular system receives tracheæ and likewise the genital cavities with their outlets and accessory apparatus.

As the development of the genital glands has already begun during the larval state, so during all the pupa state it steadily goes on, the copulatory pouch, the accessory glands, and *receptaculum seminis*, are developed with the new alimentary canal in the last section of the period of development. The genital glands of the male only attain their development during the pupal state. The eggs are developed directly after the exclusion of the fly.

The final perfection of the external form is the coloring of the chitinous skin. Shortly after, on the 18th to 20th day, follows the hatching of the egg.

ADDRESS OF PROFESSOR JOSEPH LOVERING.*

GENTLEMEN AND LADIES OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—

WHEN the States General of France were assembled for the last time at Versailles, after a long interval of inactivity, and an inaugural address was pronounced by the Bishop of Nancy, Mirabeau passed upon his performance the sweeping criticism that he had missed the grandest opportunity ever offered to man for saying something or holding his tongue. And, whenever this Association, comprising not only those who teach, but many who create science, assembles, as it now does, to listen to the address of its retiring President, if he is duly sensible of his responsibility, he would gladly avail himself of Mirabeau's alternative, either of being equal to the occasion or of being silent. But the rule of the Association, adopted in the original draft of the constitution at Philadelphia, and the example of my predecessors which I am unwilling to reverse, leave me no choice; and when I see around me, not the terrible monsters of the French revolution, maddened by the miseries of a downtrodden country, but calm and high-minded lovers of truth, I feel sure of a just and generous criticism. Welcome, then, the precious opportunity, enjoyed by the President

*The retiring President of the American Association for the Advancement of Science, delivered at the Hartford meeting.

of this Association, of discussing some of the great themes of science before an audience which has for its nucleus the original investigators, discoverers, and inventors in the country, and which like the sun, is surrounded by an extensive chromosphere only a little less brilliant than the central body by contrast; and let my earnest endeavor be not to abuse or waste the great privilege.

I am confronted on the very threshold of my address by the doubt whether it were better to beat out the little bit of golden thought, for which I have time and capacity, into a thin leaf which shall merely gild the whole vast surface of scientific investigation, even for a single year, or to condense it into a solid though minute globule, only big enough and bright enough to light up some narrow specialty. The general practice which prevails, of selecting a President alternately from the two principal sections into which the Association is divided, will justify me in paying my particular addresses to the physical sciences, knowing that the large and active department of Natural History will be properly treated in its turn by those most competent to do it. Not even the capacious mind of a Goethe, a Humboldt, a Whewell, or a Herbert Spencer is large enough to give a decent shelter to all the subjects which come within the scope of this Association. At the same time I must say that I sympathize with the remarks made by President Hunt at Indianapolis, when he questioned the propriety of excluding geology from the ranks of the physical sciences; only I would give them a still wider significance. Physical science is distinguished from natural history not so much by its subjects as its methods. In my imagination I can picture to myself all these subjects as being handled in the same masterly grasp of mechanics and mathematics by which the physical astronomer holds in his hands the history and the destiny of the solar system. What is only a dream or a fancy now may become a reality to the science of the future. Why, asked Cuvier, may not natural history some day have its Newton: to whom the laws of circulation of the sap and the blood will be only as the laws of Kepler. With such an endorser, I may venture to quote these words of a consummate mathematician without fear of their being cast aside by the naturalists as one of Bacon's Idols of the Tribe. "An intelligence which at any given instant should know all the forces by which nature is urged and the respective situations of the beings of which nature is composed, if, moreover, it were suffic-

iently comprehensive to subject these data to calculation, would include in the same formula the movements of the largest bodies of the universe and those of the slightest atom. Nothing would be uncertain to such an intelligence, and the future no less than the past would be present to its eyes." The time has already come when a knowledge of physical laws and familiarity with the instruments of physical research are indispensable to the naturalist. I would not recommend that dissipation of intellectual energy, which will make a man superficial in all the sciences but profound in none. But Helmholtz has established, by his own example, the possibility of being an eminent physiologist and, at the same time, standing in the front rank of physicists and mathematicians. The restlessness of human inquiry will never be satisfied with knowing what things are, until it has also discovered how and why they are, and until all the relations of space, time, matter, and force, in all the kingdoms of nature, have been worked out with mathematical precision.

It is a happy circumstance in the history of science, that this vast mechanical problem did not rush upon the mind at once in all its crushing generality. The solar system, with a despotic sun at the centre, competent to overrule all insubordination among planets and comets and check all eccentricities and jealousies, and so far isolated from neighbouring systems as to fear nothing from foreign interferences and entangling alliances, presented a comparatively simple problem: and yet the skill and labor of many generations of mathematicians have not yet closed up the argument upon this first case. On the orbits of this domestic system they have been sharpening their tools for higher and more delicate work. The motions of binary stars have also been brought under dynamical laws, and partially subjected to the rule of gravitation, so far as the astronomer can judge from the best observations which he can make upon those remote objects. But when he launches out, with his instruments and his formulas, into clusters of stars, even those of greatest symmetry, he is wholly at sea, without chart or compass or lighthouse, and with no other illumination than that which comes from a prophetic demonstration in Newton's Principia. The mathematician has here to treat, not with an unlimited monarchy, as in the solar system, but with a republic of equal stars, and the dynamical condition of the clusters is involved in all the obscurity of molecular mechanics; for

it matters not whether the individual members of a system are atoms or worlds, if the intervening spaces have corresponding magnitudes. Even in astronomy, the inspiration of mechanics and the pride of mathematics, how trifling is the region which has been subjugated to the rigid rules of the exact sciences when compared with the immense territories which remain under the jurisdiction of natural history, and must be studied, if at all, by the methods of the naturalist, though with an inverted microscope.

If now we circumscribe our outlook by the line which marks where physical science ends and natural history begins, it will be possible to examine only a few of the salient points in the prospect before us: and what these are will depend upon the point of view which we select. Whewell presents the history of any science at each of its successive epochs as circulating around one powerful mind, which figures as the hero of the drama: and whatever immediately precedes or follows is only the prelude or the closing strain to the great movement. In the philosophy of Comte, every science passes through a theological and metaphysical crisis before it reaches the healthy condition of positive knowledge, and its whole history is written out by him in these three acts. With Buckle, the progress of science, without which there could be no history, is coincident with the advance in civilization; but the action begins with science, and the reaction only comes from external causes. All that science and civilization demand is perfect freedom of thought. The worst enemy of both is the protective spirit in church and state, the former telling men what they must believe, the latter what they must do.

Each of these views of scientific development may be true but not to the exclusion of all others. Metaphysical blindness or theological prejudice may block the way of science or defame its fair name. It has been stated that six members of the ultraclerical party at Versailles voted against the appropriation for securing observations of the approaching transit of Venus, because they did not believe in the Copernican system, and this too while the echoes of the celebration of the four hundredth birth-day of Copernicus are still resounding over the earth. So also, circumstances and even accidents may shape the course of discovery: the happiest of all accidents, however, being the appearance on the stage of the discoverer himself.

The point of view which I have chosen for reviewing the close

and advancing columns of the physical sciences is this:—Are there any improvements in the weapons of attack, or have any additions been made to them? These are of two kinds:—1. Instruments for experiment, and 2. The logic of mathematics. These are the lighter and the heavier artillery in this peaceful service.

If we cast a hurried glance over that long period of experimental research which began with Galileo and ended with Davy, we recognize, as the chief instrumentalities by which physical science has been promoted, the telescope, the microscope, the pendulum, the balance, and the voltaic battery. It is not necessary for me to enlarge upon the strength and accuracy which the battery and the balance have given to chemistry, or on the stretch and precision of vision which the telescope and microscope have bestowed on astronomy and physics. These instruments, the veterans of many a hard fought battle, science still enjoys: not superannuated by their long service but continually growing in power and usefulness. The little opera-glass with which Galileo first lifted the veil from the skies and awoke the thunders of the Vatican has blossomed out into the magnificent refractors of Cambridge, Chicago, and Washington. The little reflector with which Newton, by a happy mistake, expected to supplant the lens, has grown into the colossal telescopes of Herschel, Rosse, and the Melbourne observatory. The spasmodic, momentary action of Davy's batteries, sufficient, however, to inaugurate a new era in chemistry, has been superseded by constant currents, which grumble not at ten hours a day. After lighting up the forelands of a continent during the night they are fresh to work an ocean telegraph the next morning. With all my wonder at this mysterious instrument which serves so faithfully the cause of science and civilization, with renewed admiration of the microscope and the telescope, one of which transforms an invisible speck of matter into a universe and the other collects the immensity of the heavens into a little celestial globe upon the retina of the eye, I must pause for a moment to eulogize that simplest and most modest of scientific tools, the pendulum.

With the eye of science Galileo saw in the leaning Campanile at Pisa, not a freak of architecture, but the opportunity of experimenting on the laws of falling bodies: and, in the adjacent cathedral where others admired the marble pavement or the vaulted roof, the columns, statues, or paintings, his attention was caught

by the isochronous vibrations of the chandelier, which during the long centuries has never been absolutely at rest. When it is said that the pendulum has no rival as a standard of length except the metre, that it furnishes an exact measure of time, and that time is an indispensable element in the study of all motion, and also the most available means of obtaining longitude on the earth and right ascension in the heavens, a strong case has been made out for the practical and scientific usefulness of Galileo's discovery. During the long years of doubt in regard to the true figure of the earth, the pendulum maintained the cause of Newton in opposition to the erroneous reports of the geodesists, until Maupertuis, by a new measurement, flattened, as has been pithily said, the earth and the Cassinis at the same time. The shape, rotation, and density of the earth; the diminution of terrestrial gravity with an increase of distance from the centre; the local attractions of mountains, and secrets hidden below the surface of the planet, have been discovered or verified by the declarations of the pendulum: which, whether in motion or at rest, has never tired of serving science. And, in a wider sense, the pendulum has done for the electric and magnetic forces what, in its restricted meaning, it did for gravity. That which Borda failed of accomplishing in the measurement of arcs the pendulum realizes in its measurement of time: it multiplies its observations, eliminates its own errors, strikes its own average, and presents to science the perfect result. In 1851, a crowd of spectators was assembled in the Pantheon of Paris to witness the first performance by the pendulum of the new part prepared for it by Foucault: in which, obedient to its own inertia, and indifferent to the earth's rotation, it preserves the parallelism of its motion: an experiment startling though not wholly unanticipated, and which has made the circuit of the earth. The new contrivance of Zöllner promises to indicate changes in the direction of a force as accurately as the common pendulum measures intensity.

Let us now consider what the physicists of our own day, and their immediate predécessors, have added to their rich inheritance of instrumental means, remembering all the time that, however impressive from their novelty these additions may be, and however manifold their applications, they have only supplemented the experimental methods which have been described without supplanting them. For the most part, the later devices would be useless without the coöperation of the earlier ones.

An interesting event in the history of science, which must be known to many of you, has taken place during the current year. In 1824, Poggendorff began to edit the *Annalen der Chemie und der Physik*. Under his supervision 150 volumes have been issued, containing 8,850 distinct communications from 2,167 different authors, the 193 papers of H. Rose outnumbering those of any other contributor. The history of physical and chemical discovery during the last fifty years might be written out of the materials treasured up in this single journal. In recognition of the signal service which Poggendorff has hereby rendered to science, his friends assumed the editorship of one volume in 1874, which is called the Jubilee volume [Jubelband].

In 1826, Poggendorff described in volume vii. of his journal a device of his own invention for observing with exceeding nicety the movements of a magnetized bar. A mirror was attached to the bar and moved with it. From this mirror a beam of light was reflected into a theodolite. This was the origin of the happy thought of amplifying a trifling motion by making the finger of a long and delicate ray of light serve as a weightless pointer. A few years later, this idea was embodied by the mathematician, Gauss, in an instrument which he called the magnetometer. Since that time, it has been continually budding out in new applications, scientific and practical. I need only recall to your recollection the beautiful method of Lissajous for compounding the vibrations of tuning-forks, and tracing in golden lines the curves which are characteristic of different musical intervals and varied phases of vibration. A new chapter has been opened in mechanics for describing and explaining these strange and nameless curves; and, in acoustics, the ear has been dispossessed by the eye of what would seem to be its own by right divine, and it is no longer the best scientific judge of sounds. By new devices Koenig has translated time into space and made visible the individual vibrations of the invisible air; and, in numerous ways, the mechanism of sound is as real to the eye as the sensation is to the ear.

With a bare allusion to the fact that every message which passes over the cable telegraph is a tribute of indebtedness to the simple but comprehensive method of Poggendorff, I pass to two other cases of great difficulty and wide significance in which the same method has triumphed. I refer to the determination of the velocity of electricity and the velocity of light.

When Wheatstone devised and executed the ingenious experiment of producing three electrical sparks, not strictly at the same instant, but after the brief interval required by electricity to travel over one quarter of a mile of copper wire, and then of observing, not the sparks themselves, but their images, as seen in a mirror revolving with the prodigious velocity of 800 turns in a single second, and from the prolongation and relative displacement of these images deducing the velocity of electricity, the duration of the electrical light, and the duality in the direction of the transmitted disturbance, he delighted the brotherhood of science by the skill and boldness of his attempt and astonished it by the extravagance of his results. For twenty years no one ventured to repeat the difficult experiment. When at length it was tried by Feddersen, and more recently by our own associate, Rood, the values which they assigned to the duration of the electrical light, and which could not be challenged, made still the wonder grow. So far as this mode of experimenting concerns the velocity of electricity, Wheatstone stands alone: and his estimate of this velocity (the largest known velocity in the universe unless we count in the velocity of gravitation) has never been brought to a second trial. Indirectly, it has been tested by some of the operations conducted upon land and ocean lines of telegraph. When the local times of two places are compared by means of electro-magnetic signals, sent alternately in opposite directions, the difference of longitude and the transmission-time of electricity can be disentangled from one another, by the strategy of mathematics, and the most probable value computed for each. The velocity which has been calculated from these longitude-campaigns falls far below that credited to Wheatstone. The apparent discrepancy is explained by a misinterpretation of Wheatstone's experiment. An experiment which proves that electricity runs through one quarter of a mile of wire *at the rate* of 288,000 miles a second does not justify the inference that it would move over 288,000 miles in one second. Anomalous as the case may be, electricity has no velocity in the ordinary sense. The transmission time of the electrical disturbance is proportioned to the square of the distance to be travelled. Therefore, the velocity has no constant fixed value, but varies with the length of the journey. This law, which is deduced from the mathematical theory of Ohm, introduces order among the experiments where, otherwise, there would be chaos. It is not surprising that Wheat-

stone and the readers whom he addressed were misled by the original facts. Few men, who have rendered signal services to science, and who have finally reached the highest pinnacle of fame, have suffered more from poverty and neglect, and waited longer for a recognition of their merits, than the modest student of Nuremberg. The slender volume which will perpetuate his name was indeed published at Berlin in 1827, and antedates Wheatstone's experiment by seven years. But the book was treated with contempt by a minister of state, to whom Ohm presented a copy, at his university of Cologne, and was first brought to the notice of English readers in 1841, when an English translation of it was effected through the agency of the British Association, and the Copley medal was presented to Ohm by the Royal Society of London. As late as 1860, when the same work was rendered into French, the translator admits that the mathematical theory of Ohm on the galvanic circuit, the elements of which have since rapidly circulated in popular text-books, was almost unknown in France, that high seat of science. If the serene but steady light of mathematics had not been dimmed by the blaze of experimental successes, and the teachings of Ohm had been heeded sooner, the science of electricity would have been the gainer, and the men of science would have been saved the mortification of treating the electromagnetic telegraph as an impracticability.

When Wheatstone was a candidate to fill a vacancy among the corresponding members of the French Institute, it was objected that he had only made a brilliant experiment, but had not discovered a new principle. Arago came to his rescue and asserted that he had introduced a powerful and fertile method of experimentation which would be felt in other sciences besides electricity. The French physicist lost no time in devising means for making good these claims. If it could be proved experimentally that the velocity of light was greater in air than in water a capital fact in the contending theories of light would be settled forever. Arago planned the experiment and pressed its feasibility upon the Academy of Sciences with all the power and eloquence of his nature. At last he roused two younger physicists to undertake what his growing infirmities prevented him from doing with his own hands. The result declared in favor of undulations, and a fatal blow was dealt to the corpuscular theory of light which had vexed science since the days of Newton. If Fizeau and Foucault drew their in-

spiration from Arago, they owed their success to nothing except their own skill in devising and executing. Having tried the temper of their steel on this easier problem, they were ready for the grand attack, which was to measure the absolute velocity of light.

The instrumental arrangements of these two experimentalists agreed only in the part which each borrowed from Poggendorff: the details differed so widely as to give to whatever agreement might appear in their results the force of an irresistible argument for their accuracy. The velocity of light, as found by Fizeau in 1849 by the artificial eclipses which the teeth of his revolving wheel produced, exceeds by about six per cent. the velocity which Foucault obtained, in 1862, with the moving mirror. The arithmetical mean of the two values comes very close to the astronomer's estimate of the velocity of light. But this simple average is precluded unless it can be proved that the two experiments are entitled to equal weight. The internal evidence, expressed by what mathematicians call the probable error, manifested a decisive preference for Foucault's result, and it has met with general acceptance. The soundness of the scientific judgment in this case has been placed beyond all cavil by Cornu, who has recently repeated Fizeau's experiment, with additional precautions, and resolved the discord into a marvellous accord. Fizeau's experiment, in spite of the numerical defect, was hailed as one of the grandest triumphs of experimental skill. In 1856, he received the prize of 30,000 francs which the Emperor of the French had founded, to be given for the work or the discovery, which, in the opinion of the five academies of the Institute, had conferred the greatest honor and service upon the nation. Hitherto, it had been supposed that nothing short of an interstellar or an interplanetary space was a match for the enormous velocity of light. And yet one physicist, by using a distance of less than six miles, and another, without going outside of his laboratory, have discovered what astronomers had searched heaven and earth to find out.

By these capital experiments the science of optics has achieved its own independence. Let us see what they have done, at the same time, for astronomy. The sequences in the eclipses of Jupiter's moons are modified by the velocity of light. The aberration of starlight is a measure of the ratio between the velocity of light and the velocity of the earth. For nearly two centuries our knowledge of the velocity of light leaned upon one or the other

of these relations. If the velocity of light can be known from experiment, the problem may be reversed and the distance of the sun given to the astronomer. As soon at it appeared that Foucault's estimate of the velocity of light fell short of the astronomical valuation by about three per cent, it was certain that either the experiment was in error, or the received aberration was too small, or the reputed distance of the sun was too large. An error of three per cent. in the experiment or in the aberration was inadmissible. But it was conceivable that the distance of the sun should be at fault, even to this extent. The popular announcement that Foucault had picked a flaw in the astronomer's work was not correct. Astronomers had always known what those who pinned their scientific faith on text-books did not expect: that the problem of finding the sun's distance was an exceedingly delicate case, and that an ominous cloud of uncertainty hung over their wisest conclusions. Whenever it is possible to interrogate nature in more ways than one, science is not satisfied with a single answer, nor with all the answers unless they agree. The transit of Venus, the parallax of Mars, and the tables of the Moon, each can tell the sun's distance. But their testimony was contradictory, and neither one at all times repeated the same story. The question was, which to believe. Since 1824, when Encke published his exhaustive computations on the last transits of Venus, the distance which they assigned to the sun has been acquiesced in as the most probable. But the moon, as has been said, has always been a thorn in the sides of mathematicians. While practical and theoretical astronomers have been reducing its motions to stricter discipline, the suspicion has been steadily gaining strength in their minds that the distance adopted from the transits was too large. The effect of Foucault's experiment was to intensify the doubt. The case of the twin transits of the last century, thought to have been closed forever by Encke, has recently been opened again by the astronomer Stone. When Venus has nearly entered upon the sun, the moment of interior contact is preluded by the formation of a slender ligature (called the black drop) between the nearest parts of the two discs; caused, perhaps, by irradiation. One observer has recorded the time when this ligature began, another the time when it was broken. In working up the observations of the last transits, both classes were not combined indiscriminately. Mr. Stone has reëxamined the documents, classified differently the

materials, and extracted from them two new and independent values for the sun's parallax. The reconciliation which he has suddenly brought about between the experiments of Cornu and Foucault, the motions of the moon, and the transits of Venus, is as perfect as it is surprising. Nevertheless, the approaching transits of Venus, the earliest of which is close upon us, will be welcomed, if not as the only possible way of solving a hard problem, at least for the confirmation which is demanded by a solution already reached: for able astronomers have dissented from the interpretation put upon the records by Stone. The minds of observers have been prepared for what their eyes are to see, in December, 1874, by the experimental rehearsal of the black drop, and the photographer's box will arrest the planet in the very act.

The consequences of Foucault's experiment, substantiated as it may be by the best astronomical evidence, are as far reaching as the remotest stars and nebulæ. The sun's distance is the astronomer's metre, through which masses, diameters, and distances are proportioned out to planets, comets, and stars. If the sun's distance is cut down by three per cent., there must be a general contraction in all the physical constants of the universe. The earth only is immediately exempt from this liability. But if, as modern science teaches, the earth lives only by the triple radiation from the sun, then an earlier doom has been written for the earth also. Geology is no longer allowed to cut its garment from a past duration of unlimited extent. The numerical estimates of physical science, with a large margin of uncertainty, assign limits between which alone geology has free play. Whatever tends to reduce or enlarge those limits must be of interest to the geologist as well as to the astronomer.

This is the brilliant career, in electricity, optics, astronomy, and geology, of the little mirror, cradled in the laboratory of Poggendorff, and which has not yet seen its fiftieth birthday.

In making this exhibit of the instrumental appliances of modern physics, I will simply name the polariscope, the stereoscope, and the instruments in photography, and hurry on to the spectroscope.

The steps by which the spectroscope has attained its preëminent rank among the instruments of the physicist and the astronomer were taken at long intervals. A whole century intervened between Newton's experiments with the prism and Wollaston's improvement. The substitution of a long and narrow slit for the round

hole in the window shutter was enough to reveal the presence of the two boldest dark lines in the solar spectrum. Wollaston stood on the threshold of a rich development in science, but neither he nor his compeers were ready for it, and what he saw, novel as it was, attracted little attention. Spectrum analysis, in relation to light itself, began when Frauenhofer published, in 1817, in the memoirs of the Bavarian Academy, an account of his experiments on the direct and reflected rays of the sun, on starlight, and various artificial sources of light: dispersing the rays by prisms of fine Munich glass and then receiving them into a theodolite. Frauenhofer repeated some of his experiments in the presence of the younger Herschel, but for many years he had the field wholly to himself. A paper by Herschel on the colors of artificial flames acquires a new interest from what has been done more recently. Between 1830 and 1860, numerous physicists, among whom are the well known names of Brewster, Miller, Wheatstone, Powell, Stokes, Gladstone, Becquerel, Masson, Van der Willigen, Plücker, and Angström, were at work upon the facts connected with the emission of light by incandescent bodies and its absorption by gases and vapors. As early as 1830, Simms had placed a lens in front of the prism, with the slit in the focus, and another lens behind the prism to form an image of the slit.

The first hint of that pregnant fact, the reversal of the bright spectrum bands of flames, came from Foucault in 1849. His experiment was repeated at Paris, in 1850, in the presence of Sir William Thomson. It was reserved for a young physicist of Heidelberg, who was not born until seven years after Frauenhofer laid the foundations, to place the keystone upon the structure on which many hands had labored: by demonstrating, in 1860, the law which is the theoretical basis of the chemistry of the heavens. Kirchhoff, with admirable frankness, is careful to say that this law had been anticipated by others, especially by Angström and Balfour Stewart, although it had not been sharply stated or severely proved. It is a singular fact that the mechanical explanation of the law, as it has been expounded by Kirchhoff, Angström, and Stokes, was partially enunciated one hundred years ago by the mathematician, Euler, when he said that every substance absorbs light of the special wave-length which corresponds to the vibration of its smallest particles. The 11th of July, 1861, will be ever memorable in the history of science as being the day

on which Magnus read, before the Berlin Academy, Kirchhoff's memoir on the chemical constitution of the sun's atmosphere, and the existence in it of familiar substances found upon the earth. Speedily, spectroscopes were multiplied, modified, and improved, and became indispensable auxiliaries in the workshop, the laboratory, and the observatory. It is not necessary to enlarge upon what this instrument has done for common chemistry, in hunting out the minutest traces of common substances and detecting new ones. The physician, the physiologist, the zoölogist, the botanist, and the technologist have shared with the chemist and the physicist the services of this powerful analyst. But it is the highest prerogative of the spectroscope to be able to make a chemical analysis of celestial bodies, upon the single condition that they give to it their light. Polarization can only say whether any portion of this light is reflected. The motions which the telescope uncovers may decide in favor of a central attraction, but it is silent as to the intensity of this attraction unless the moving body belongs to the solar system. The universality of a gravitation may be proved, but not the universality of the very gravitation which pervades our own system; except by an argument from analogy. We see that one star differs from another star in glory. But what the other differences or resemblances are we know not, without the spectroscope. Henceforth astronomy possesses a new instrument of discovery, and also a new tribunal to which all speculations about the sun and the stars, the aurora and the zodiacal light, the meteors and the comets, must be brought and by which they must be judged.

I leave it to the naturalists to assign a value to the alleged anticipations of Darwin by the geometer Maupertuis, who was said to have died just before he was going to make monkeys talk. The whims and conceit of Lord Monboddo are not worthy of notice. Lamarck began life as a soldier: was a meteorologist as far and as long as Napoleon would allow him to be: perhaps he was a botanist from choice, but he was made a zoölogist, in spite of himself, by the revolutionary Convention. He was as brave in science as in war; but he expected to *create* it, by a simple effort of thought. Having demolished the modern chemistry, he turned his iconoclastic zeal into natural history. His philosophy of zoölogy was published a few years after the cosmogony of Laplace; in which the mathematician broaches the theory of evo-

lution as a mechanical doctrine, capable of explaining certain characteristics of the solar system, about which the law of gravitation is silent. Whoever reads the stately chapters of Laplace, on the stability of the planets and the safeguards of the comets, will easily recognize expressions which are the mechanical equivalents of the principles of natural selection and the survival of the fittest. The elder Herschel hazarded the speculation, that the clusters of stars and the nebulæ which his devouring telescope had picked up, by hundreds, on the verge of the visible heavens, were genuine suns assembled under the organizing power of gravitation; and that the varieties in size, shape, and texture, were produced by differences of age and distance. The imagination of Herschel and other astronomers has taken a loftier flight. To them many of the nebulæ are not clusters of stars, but unborn solar systems, waiting for that consolidation by which planets are evolved and a central sun is formed, and destined thus to repeat the cosmogony of the home system. Comte claims that he has raised the nebular hypothesis to the rank of positive science. He supposes the stupendous enginery of evolution to be reversed. He follows, with his mathematics, the expanding sun backwards into chaos, until it has absorbed into its bosom even the first born among the planets, and finds, at every stage, numerical confirmation of what Laplace threw out as a plausible conjecture. As Mr. Mill and other writers of note have accepted this authority, it should be understood that Comte has never published the data or the process of his computations. By whatever other inspiration he arrived at his conclusion, he was not brought to it by his mathematics. He has said all that is necessary to show that he ignored all the difficulties of the problem, and dodged the only solution that could give satisfaction. The cosmogony of Laplace, with all its fascination, must be excluded from exact mechanics and remanded back to its original place in natural history, by the side of the more general nebular hypothesis of Herschel. All other cosmogonies which poetry or science have invented are childish in comparison with this: and no one would desire to banish it from science altogether, until it is disproved or displaced by something better. Instead of *deciding*, it must *share* the fate of the all-embracing cosmical speculation of Halley. How uncertain that fate is we may be taught by the frequency with which the preponderance of evidence has shifted from one

side to the other, during the last fifty years. The irresolvability of many of the nebulæ, by powerful telescopes, led Herschel to espouse the cause of a diffuse primeval matter, out of which worlds were fashioned. No wonder that, in particular cases, the negative evidence was sometimes turned into positive evidence on the other side, by improvements in telescopes. Although every nebula which deserted from the nebular hypothesis strengthened the suspicion that the remaining irresolvability was purely optical, a sufficient amount of negative evidence would probably have always existed to create more than a doubt in the minds of many astronomers. On the discovery of spectrum analysis, observers rallied around it, in the hope of finding an escape from the dilemma: and this new hope has not been disappointed. The continuous spectra of some nebulæ prove them to be suns, enveloped in more or less of atmosphere. The broken spectra of other nebulæ show that they are in the condition of an incandescent gas. The classification which the spectroscope makes of the nebulæ corresponds so well with their telescopic appearance as to justify the confidence which one class of astronomers had in their way of deciding on the truth of the nebular hypothesis. While the spectroscope has manifested varieties of material, color, temperature, and consolidation in nebulæ and stars, both single and composite, beyond anything which the perfected telescope could ever have revealed, it has at the same time found enough of earth in all of them to make man feel at home any where in the visible universe. The fact that certain well-known substances on this planet pass current everywhere in nature leads irresistibly to the conclusion that all the specimens came originally from the same mint. It is the legitimate office of science to reduce the more complex to the simple: to explain, if possible, the existing state of matter by an anterior state. The nebular hypothesis, which attempts to do this, no longer starts from a conjecture but a reality: *viz.*, the existence of diffused incandescent vapor; and science will hold on to it, until a better theory of mechanical development is found. — *Concluded in next number.*

REVIEWS AND BOOK NOTICES.

THE PRINCIPLES OF SCIENCE.*—Though each scientist, whether consciously or not, does his work on principles underlying all useful and durable efforts, yet the methods have been gradually developed, and the laborer in one department may be ignorant of the mode of procedure in others quite remote from his line of study. The author discusses the methods common to all the sciences, though with a bias towards physical science, particularly physics, chemistry and astronomy. As a result we have a book which we are sure will win the sympathy of the reader, as it is an earnest and sensible treatise. Wherever we have opened the volume we have been attracted by the interest and clearness of the style, and the general tone of the discussion which, though on the whole conservative, is in full accordance with the spirit of modern science.

The chapters on the use of hypothesis, and the character of the experimentalist are capital. Professor Jevons boldly says "it is wholly a mistake to say that modern science is the result of the Baconian philosophy; it is the Newtonian philosophy and the Newtonian method which have led to all the great triumphs of physical science, and I repeat that the 'Principia' forms the true 'Novum Organum.'" If we mistake not, the theory of evolution, as suggested by Lamarck, Spencer, Darwin and others is a result of the Newtonian rather than the Baconian method; certainly it may be said in its present stage to be a "hypothetical anticipation of nature," valuable as it is as a means of research.

In the chapter on Classification the author states his belief that a natural classification is an "arrangement which would display the genealogical descent of every form from the original life germ. Those morphological resemblances upon which the classification of living beings is almost always based are inherited resemblances, and it is evident that descendants will usually resemble their parents and each other in a great many points." Much importance is given to the bifurcate or dichotomic arrangement so universally used in descriptive biology.

* The Principles of Science; a treatise on Logic and Scientific Method. By W. Stanley Jevons. Special American Edition, bound in one volume. New York. MacMillan & Co., 1874. 8vo. pp. 480.

How a mind trained in logic and the methods of exact science looks upon the theory of evolution, may be seen from the following extract:—

"The genealogical view of the mutual relations of animals and plants leads us to discard all notions of any regular progression of living forms, or any theory as to their symmetrical relations. It was at one time a great question whether the ultimate scheme of natural classification would prove to be in a simple line, or a circle, or a combination of circles. Macleay's once celebrated system was a circular one, and each class-circle was composed of five order-circles, each of which was composed again of five tribe-circles, and so on, the subdivision being at each step into five minor circles. Thus he held that in the animal kingdom there were five sub-kingdoms—the Vertebrata, Annulosa, Radiata, Acrita, and Mollusca. Each of these was again divided into five—the Vertebrata consisting of Mammalia, Reptilia, Pisces, Amphibia, and Aves.* It is quite evident that in any such symmetrical system the animals were made to suit themselves to the classes instead of the classes being suited to the animals.

We now perceive that the ultimate system will be an almost infinitely extended genealogical tree, which will be capable of representation by lines on a plane surface of sufficient extent. But there is not the least reason to suppose that this tree will have a symmetrical form. Some branches of it would be immensely developed compared with others. In some cases a form may have propagated itself almost from primeval times with little variation.

In other cases frequent differentiations will have occurred. Strictly speaking, this genealogical tree ought to represent the descent of each individual living form now existing or which has existed. It should be as personal and minute in its detail of relations, as the stemma of the kings of England. We must not assume that any two forms are absolutely and exactly alike, and in any case they are numerically distinct. Every parent then must be represented at the apex of a series of divergent lines, representing the generation of so many children. Any complete and perfect system of classification must regard individuals as the infimæ species. But as in the lower races of animals and plants the differences between individuals are usually very slight, and apparently unimportant, while the numbers of such individuals are immensely great, beyond all possibility of separate treatment, scientific men have always stopped at some convenient but arbitrary point, and have assumed that forms so closely resembling each other as to present no constant difference were all of one kind. They have, in short, fixed their attention entirely upon the main features of family difference. In the genealogical tree which

*Swainson, 'Treatise on the Geography and Classification of Animals,' 'Cabinet Cyclopædia,' p. 201.

they have been unconsciously aiming to construct, diverging lines meant races diverging in character, and the purpose of all efforts at so-called natural classification was to trace out the relationships between existing plants or animals. Now it is evident that hereditary descent may have in different cases produced very different results as regards the problem of classification. In some cases the differentiation of characters may have been very frequent, and specimens of all the characters produced may have been transmitted to the present time. A living form will then have, as it were, an almost infinite number of cousins of various degrees, and there will be an immense number of forms finely graduated in their resemblances. Exact and distinct classification will then be almost impossible, and the wisest course will be not to attempt arbitrarily to distinguish forms closely related in nature, but to allow that there exists transitional forms of every degree, to mark out if possible the extreme limits of the family relationship, and perhaps to select the most generalized form, or that which presents the greatest number of close resemblances to others of the family, as the *type* of the whole.

Mr. Darwin, in his most interesting work upon Orchids, points out that the tribe of Malaxeæ are distinguished from Epidendreæ by the absence of a caudicle to the pollinia, but as some of the Malaxeæ have a minute caudicle the division really breaks down in the most essential point.

'This is a misfortune,' he remarks,* 'which every naturalist encounters in attempting to classify a largely developed or so-called natural group, in which, relatively to other groups, there has been little extinction. In order that the naturalist may be enabled to give precise and clear definitions of his divisions, whole ranks of intermediate or gradational forms must have been utterly swept away: if here and there a member of the intermediate ranks has escaped annihilation, it puts an effectual bar to any absolutely distinct definition.'

In other cases a particular plant or animal may perhaps have transmitted its form from generation to generation almost unchanged, or, what comes to the same result, those forms which diverged in character from the parent stock, may have proved unsuitable to their circumstances, and may have perished sooner or later. We shall then find a particular form standing apart from all others, and marked by various distinct characters. Occasionally we may meet with specimens of a race which was formerly far more common but is now undergoing extinction, and is nearly the last of its kind. Thus we may explain the occurrence of exceptional forms such as are found in the Amphioxus. The Equisetaceæ perplex botanists by their want of affinity to other orders of Acrogenous plants. This doubtless indicates that their genea-

* Darwin, 'Fertilization of Orchids.' p. 159.

logical connexion with other plants must be sought for in the most distant past ages of geological development.

Constancy of character, as Mr. Darwin has said,* is what is chiefly valued and sought after by naturalists; that is to say naturalists wish to find some distinct family mark, or group of characters by which they may clearly recognize the relationship of descent between a large group of living forms. It is accordingly a great relief to the mind of the naturalist when he comes upon a definitely marked group, such as the Diatomaceæ, which are clearly separated from their nearest neighbours the Desmidiaceæ by their siliceous framework and the absence of chlorophyll. But we must no longer think that because we fail in detecting constancy of character the fault is in our classificatory sciences. Where gradation of character really exists, we must devote ourselves to defining and registering the degrees and limits of that gradation. The ultimate natural arrangement will often be devoid of strong lines of demarcation.

Let naturalists, too, form their systems of natural classification with all the care they can, yet it will certainly happen from time to time that new and exceptional forms of animals or vegetables will be discovered, and will require the modification of the system. A natural system is directed, as we have seen, to the discovery of empirical laws of correlation, but these laws being purely empirical will frequently be falsified by more extensive investigation. From time to time the notions of naturalists have been greatly widened, especially in the case of Australian animals and plants, by the discovery of unexpected combinations of organs, and such events must often happen in the future. If indeed the time shall come when all the forms of plants are discovered and accurately described, the science of Systematic Botany will then be placed in a new and more favourable position, as remarked by Alphonse Decandolle.†"

From paying too much attention to a classification by types, *i.e.*, by selecting one typical form and grouping around it allied forms, Professor Jevons believes that "a certain laxity of logical method is thus apt to creep in, the only remedy for which will be the frank recognition of the fact that according to the theory of hereditary descent, the gradation of characters is probably the rule, and the precise demarcation between groups the exception."

The author agrees with those naturalists who regard the existence of any such groups as genera and species as "an arbitrary creation of the naturalist's mind;" an important result of the establishment of the theory of evolution being "to explode all notions

*'Descent of Man,' vol. i, p. 214.

†'Laws of Botanical Nomenclature,' p. 16.

about the existence of natural groups constituting separate creations." The whole is in his opinion a question of degree.

What is the outcome of the tendencies of modern scientific thought, materialism and the reign of physical law? The logical and courageous philosopher with the modesty of true science will exclaim with our author, after a survey of the little that is positively known of the laws of nature that "before a rigorous logical scrutiny the Reign of Law will prove to be an unverified hypothesis, the Uniformity of Nature an ambiguous expression, the certainty of our scientific inferences to a great extent a delusion."

The closing paragraphs of the book leave an excellent impression, and its whole tendency is to induce that attitude of the mind which characterizes the true philosopher who, as our author quotes from Faraday, "should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be biased by appearances; have no favourite hypothesis; be of no school: and in doctrine have no master. He should not be a respecter of persons, but of things. Truth should be his primary object. If to these qualities be added industry, he may indeed hope to walk within the veil of the temple of nature."

SCAMMON'S MARINE MAMMALS OF THE NORTHWESTERN COAST AND AMERICAN WHALE-FISHERY.*—The title of Capt. Scammon's important work indicates sufficiently its object and scope. It is divided into three parts, besides containing a lengthy appendix. Part I (comprising 112 pp.) is devoted to the natural history of the Cetacea, or the whales, porpoises and dolphins. Part II (69 pp.) treats in a similar way of the Pinnipedia, or the seals, while Part III (87 pp.) contains a concise and very interesting history of the American Whale-fishery. In Part I, the author has before him an almost wholly unworked field, and one in which he proves himself to have been an intelligent and faithful laborer. The marine mammals, and especially the Cetacea, from the nature of the element in which they live, as well as their generally unwieldy proportions and wary dispositions, are among the most difficult animals to study that the naturalist encounters. Only a

* The Marine Mammals of the Northwestern Coast of North America, described and illustrated: together with an account of the American Whale-fishery. By Charles M. Scammon, Captain U. S. Revenue Marine. San Francisco: John H. Carmany & Co. 1874. 4to, 319 pp., with 27 lithographic plates and numerous woodcuts.

naturalist who combines with his scientific knowledge the experience of a whaleman could even hope to give more than a very inadequate account of the habits of these "monsters of the deep." The immense size of many of the larger Cetacea, and the great infrequency of opportunities of observing them stranded, or wholly removed from the water, render it very difficult to get either accurate figures of them or more than approximate measurements. Capt. Scammon seems to have enjoyed rare opportunities for collecting material for his book, and an excellent preparation for the task he has undertaken, for, besides his twenty years of personal experience and observation, he has availed himself of information acquired by other intelligent whalemen. Hence his biographies, statistics of size, and his figures of the animals are far more satisfactory than anything that has previously appeared treating of the general history of these little known animals. Fourteen pages, for instance, are devoted to the California gray whale (*Rhachianectes glaucus* Cope) in which is detailed not only its habits and distribution, but the methods and dangers of its pursuit and capture; the article being also illustrated with three lithographic plates. The bowhead or great polar whale (*Balæna mysticetus*) receives an equally extended notice, this species being "by far the most valuable in a commercial point of view of all the *Balænidæ* and is the chief object of pursuit by the whaleman in the northern seas." The yield of oil, in large individuals of this species, is said to exceed sometimes two hundred and seventy-five barrels, while the product of baleen may be upwards of three thousand five hundred pounds. The whaling grounds are described at length, as is also what is termed "Bowhead Whaling." Capt. Scammon considers it as conclusively proved that this species passes from the Atlantic to the Pacific, "or rather," as he expresses it, "from the Atlantic Arctic to the Pacific Arctic by the North," and believes that air-holes always exist in the ice which covers the arctic waters, even in the coldest latitudes. About a dozen pages are devoted to the sperm whale (*Physeter macrocephalus*), and about five to the orca, or killer, which is, of all the Cetacea, the most rapacious and terrible to the larger denizens of the sea.

In Part II the ground is less new, but here very material contributions are made to a better knowledge of several species of the larger Pinnipeds, especially of the sea elephants, sea lions, and fur seals of the California coast, and also of the sea otter

(*Enhydra marina*), which is singularly included with the Pinnipedia! The history of the wholesale destruction of these animals for commercial purposes possesses a peculiar and rather melancholy interest. Besides adding much new matter to the history of the fur seal as observed by the writer on the California coast, the chapter is made much more complete by the quotation of the greater part of Capt. Bryant's excellent article on the fur seals of Alaska, published a few years since in the Bulletin of the Museum of Comparative Zoology.*

Part III is possibly the most interesting portion to the general reader, giving as it does not only a succinct chronological and statistical history of the American Whale-fishery, but also vividly portraying the privations, dangers, and excitements attending this daring pursuit, as well as the special training, energy and skill necessary to its successful prosecution. New England may well be proud of the names so favorably mentioned as the founders and leaders in this great enterprise, whose vessels were often the first to bear our national emblem to remote waters and distant seaports.

In the appendix is given a systematic "catalogue of the Cetacea of the North Pacific Ocean" by Mr. W. H. Dall, of the U. S. Coast Survey, prepared with special reference to Capt. Scammon's monograph in the preceding pages of the general work. This catalogue embraces also many osteological notes and descriptions of new forms. The list comprises about forty-four species, which Mr. Dall observes, "appear to be more or less thoroughly characterized," but ten are of unknown habitat. "Leaving these out," he adds (with all species based on insufficient material), we have as the approximate distribution of the known Pacific Cetacea: Japan, five species; northern seas, six species, including two or three which visit California; warm seas and South Pacific, eleven species; coast of Western North America, from the Aleutian Islands to Central America, eighteen species, including several visitors from the Arctic Seas."

The volume closes with a "glossary of words and phrases used by whalemen," and a list of the "stores and outfits" usually taken out by a first-class whale-ship for a Cape Horn voyage.

While Capt. Scammon's work is very satisfactory in the fulness with which it deals with external characters — color, size, form, proportions, etc. — and in its biographical details, the author ab-

* Vol. II, pp. 95-108, 1870.

stains (and perhaps wisely) from a critical discussion of points of synonymy and affinity; yet it is a work that goes far towards filling a wide gap in marine mammalogy, to which subject it is a most welcome and important contribution. The publishers have spared no pains, apparently, to make the work attractive, and the illustrations are generally of a high order of execution. The work is very appropriately inscribed by the author to the memory of Louis Agassiz.—J. A. A.

BOTANY.

Botany of Wilkes' South Pacific Exploring Expedition.—Since the lamented death of Dr. Torrey, his report on the Botanical collections made by the naturalist of Wilkes' expedition on our western American coast, has been printed under the care of Prof. Gray. It makes the larger part of the 17th volume of the results of that expedition, of which, like the rest, only 100 copies are printed by Congress. A small number of extra copies have, however, been secured, at private expense; these are bound up with the preceding part of the volume, devoted to the Lower Cryptogamia of the expedition (Lichens, Algæ and Fungi) and the large plates being folded and bound in, the whole makes a stout royal quarto volume, with 29 plates. The Naturalists' Agency has this on sale, at ten dollars. The mosses of the same expedition by Sullivant, which form the first part of this same volume in the government copies, in the extra edition have the letter-press made up into imperial folio pages, in double columns, to match the 26 great folio plates. A very few copies of this handsome volume still remain in the hands of the late Mr. Sullivant's executors, and can be had for ten dollars each.

Influence of Forests on the Rainfall.—At a recent meeting of the French Academy M. M. Fautra and Sarquiau read a note relative to this subject. They found from experiments made in a forest of more than 500 hectares,* and also on a plain free from trees situated about 300 yards from the forest, that much more rain fell in the wooded part than on the plain.

* A hectare is 11,960 English square yards.

ZOOLOGY.

The Snow Goose. — On the 6th of October, 1873, I shot at Mt. Carmel, Illinois, a fine adult male *Anser hyperboreus*, which had been living with a flock of tame geese for nearly a year. The bird had been crippled in the wing the preceding fall, but the wound, which was merely in the muscles, soon healed, and it escaped by flight. It flew about half a mile, and, observing a flock of tame geese upon the grassy "commons" between the town and the river, alighted among them. It continued to stay with them, going home with the flock regularly every evening, to be fed and enclosed in the barn-yard.

My attention was attracted to this bird by its owner, Mr. Thomas Hoskinson, from whom I got the above facts; and who kindly told me that if I would shoot the bird he was willing to have it sacrificed to science. Accordingly, I repaired to the "commons" and found the flock at a locality designated. After some little search the "white brant" was discovered, being distinguished by its black quill-feathers, rather smaller size, shorter neck, black instead of bluish eyes, and the black space along the commissures of the bill. When unmolested this bird was as unmindful of a person as the tame geese, and it required chase to make it endeavor to escape, which it always did by rising easily from the ground, and flying to the river — sometimes half a mile distant.

The specimen was in fine plumage and excellent condition, and made a very clean, perfect specimen when prepared. It measured as follows: — Length, 27 inches; extent, 57; wing, 17; culmen, 2·25; tarsus, 2; middle toe, 1·75. Its weight was 5¼ lbs. Bill deep flesh-color, the upper mandible with a salmon-colored tinge, and the lower with a rosy pink flush; the terminal ungui nearly white; the commissures enclose an elongate oval space of deep black; iris very dark brown; eyelids greenish-white; tarsi and toes purple-lake, the soles of the feet dingy Naples-yellow.

A remarkable feature of this specimen is that one or two of the primaries are entirely pure white, while most of the remaining ones have longitudinal spaces, of greater or less extent, on the inner webs. The question arises, whether this is merely a case

of partial albinism, or a change produced by the modified condition of its food and mode of life.—Robert Ridgway.

GEOLOGY.

Deep sea Temperature in the Antarctic Sea.—In the Report to the Admiralty of Capt. G. S. Nares, of H. M. S. Challenger, dated Melbourne, March 25, 1874, Capt. Nares, speaking of the temperature of the ocean, especially near the pack edge of the ice, says:—"At a short distance from the pack, the surface water rose to 32°, but at a depth of 40 fathoms we always found the temperature to be 29°; this continued to 300 fathoms, the depth in which most of the icebergs float, after which there is a stratum of slightly warmer water of 33° or 34°. As the thermometers had to pass through these two belts of water before reaching the bottom, the indices registered those temperatures, and it was impossible to obtain the exact temperature of the bottom whilst near the ice, but the observations made in lower latitudes show that it is about 31°. More exact results could not have been obtained even had Mr. Siemens' apparatus been on board."

Origin of the Valley of the Rhine.—Geologists intending to travel up the Rhine should by all means read an interesting paper by Prof. A. C. Ramsay on the origin of the Valley of the Rhine, contained in the Quarterly Journal of the London Geological Society (May 1, 1874). He states that the valley during portions of the miocene tertiary period was drained by a river flowing from north southwards, and after the upheaval of the Alps the present river originated and flowed through an elevated plain formed of miocene rocks, leaving the existing plain, "which to the uninstructed eye presents the deceptive appearance of once having been occupied by a great lake."

ANTHROPOLOGY.

Extent of the Ancient Civilization of Peru.—Prof. C. F. Hart writes to the president of the Anthropological Society of Berlin, that in a journey to the river Amazon he found some pieces of pottery of which some recall curious forms discovered in Peru, and which prove that the ancient Peruvian civilization extended to the eastern side of the Andes.

MICROSCOPY.

Sphæraphides in Tea Leaves.—The present interest in the question of adulteration of tea leaves gives special importance to Mr. George Gulliver's discovery that the parenchyma of these leaves is thickly studded with sphæraphides, apparently of oxalate of lime, having a mean diameter of about $\frac{1}{1000}$ inch. They have hitherto escaped notice, being not easy to find on account of the opacity and density of the parts. Soaking, or boiling the leaves in a potash solution, separates the epidermis (which is composed of cells with sinuous margins, and smooth, taper, slightly curved hairs, with the addition of oval stomata on the under side) and exposes distinctly the parenchyma, nerves, and sphæraphides. He has found potash equally useful in exposing the crystals in other plants.

New Microscopical Societies.—A new society has been organized in Australia, known as the "Microscopical Society of Victoria." Mr. W. H. Archer is the first President.

A Microscopical Department of the Providence Franklin Society has been established, with the following officers for the present year:—*Chairman*, Professor Eli W. Blake, Jr.; *Vice-Chairman*, A. O. Tilden; *Secretary*, Professor John Peirce; *Cabinet Keeper*, N. N. Mason; *Treasurer*, Dr. C. B. Johnson.

The "Indiana Microscopical Society" was incorporated February 16, 1874. It is located at Indianapolis, and holds monthly meetings.

Appearances of the Blood in Melanosis.—M. Nepveau represents that the blood of persons affected with melanotic tumors becomes marked by the presence of an excessive proportion of leucocytes which are also filled with dark granules; the red corpuscles when seen in masses have more or less of a sepia tint; and the serum contains reddish-brown granules, and flexible casts resembling hyaline casts which seem to be derived from the capillaries.

Achromatic Bull's Eye Condenser.—This unusual accessory was exhibited by Mr. Ingpen at a late meeting of the Queckett Club.

EMBEDDING TISSUES.—At the Queckett Club wax was spoken of as the chosen material for embedding tissues preparatory to cutting thin sections. Dr. Matthews preferred paraffine to beeswax. Dr. George Hoggan, however, considered carrot preferable to wax, and elder pith better than either.

GLYCERINE MOUNTING. — According to Dr. George Hoggan, glycerine is used almost universally for mounting in France. A little paraffine is run around the edge of the cover-glass, and a solution of sealing wax painted over it.

NOTES.

PROFESSOR JEFFRIES WYMAN, of Cambridge, died suddenly at Bethlehem, N. H., on September 4th. For many years Professor Wyman had been in delicate health and obliged to spend the winter months in Florida, while the heat of summer was avoided by excursions to the mountains, and it was hoped that with the great care he was taking he would be spared for many years to come; especially did this seem probable from his apparently restored condition on his return from Florida last spring, when he seemed to have renewed vigor for the labors before him, and commenced to put the material he had collected during his Florida trips in order for publication. This was so far advanced that at the time of his decease he was engaged in printing his memoir upon the Shell-mounds of Florida, a work that it is greatly to be hoped was so far completed in manuscript as to ensure its publication, as it will undoubtedly exhibit the thoroughness and cautiousness with which his investigations were made.

Professor Wyman was born in Chelmsford, Mass., August 11, 1814. He graduated at Harvard in the class of 1833, and four years after received his degree of M. D. He then passed two years of study in Europe, and soon after returning to this country accepted the position of Professor of Anatomy at the Hampden Sidney College of Virginia, which place he held until 1847, when he accepted the Hersey Professorship of Anatomy and Physiology at Harvard, which position he held at the time of his decease. He was one of the original Trustees, appointed by Mr. Peabody, of the Peabody Museum of American Ethnology and Archæology, and had from the first held the position of Curator of that Museum which owes so much to his care and labors. He always took an active part in the Boston Society of Natural History, and

succeeded Dr. Warren in the office of president, which office he held until 1870 when the state of his health compelled him to resign the chair. He was one of the original members and first officers of the American Association for the Advancement of Science, and was also an original member of the National Academy. For many years he acted on the council of the American Academy of Arts and Sciences, and was an honored member of many other societies. Professor Wyman was of a singularly modest and retiring disposition, and though a constant and most laborious worker, his reluctance to appear in public, and his extreme modesty regarding the results he attained, has prevented the world from sharing in but a very small part of his great knowledge, as his publications have been comparatively few in number. Ever ready to assist and guide those who sought his council he was, while scientifically severe, a most genial and thorough friend, and was greatly honored and respected by his pupils and friends.

In his death humanity loses an upright, reliable and strictly honest man, and science one of the most thorough and cautious of investigators.

The French Association for the Advancement of Science held its third meeting at Lille, Aug. 20th, with a large number of foreign scientists in attendance. Over one hundred and fifty persons read papers during the meeting. One of the attractions was a visit to the new laboratory of experimental zoology at Vimereux, near Boulogne. There was also an excursion to Bruges and Antwerp. The session lasted for eight days.

The International Congress of Anthropology and prehistoric Archæology opened Aug. 7, at Stockholm, with an attendance of 800 members, of which more than 300 were foreigners. Everything betokened a brilliant meeting.

The new geological survey of Pennsylvania is being pushed with much vigor under the direction of Prof. J. P. Lesley. $30,000 annually for three years have been voted by the legislature.

Professor Carl Moebius left Kiel on the 25th of July for Mauritius. He will remain there five or six months to study the marine fauna of the island and make collections for the Prussian Universities.